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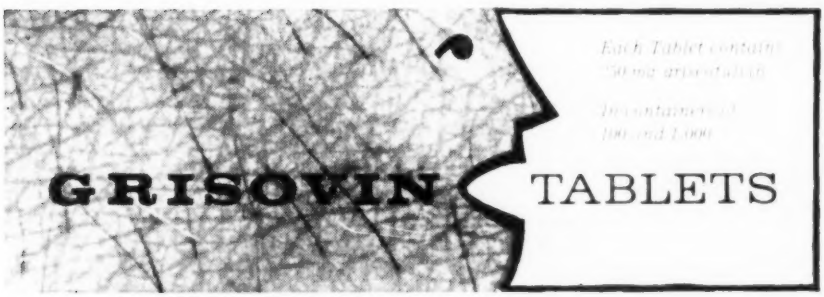

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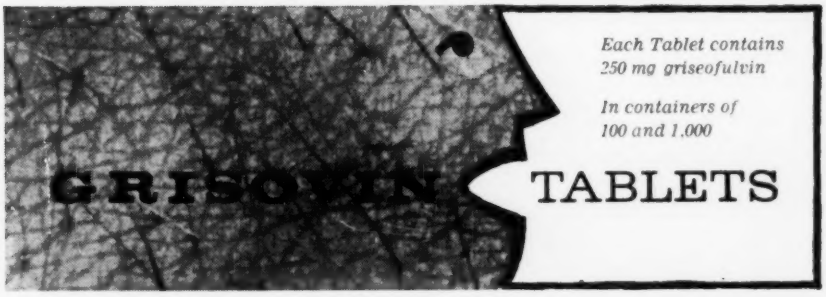

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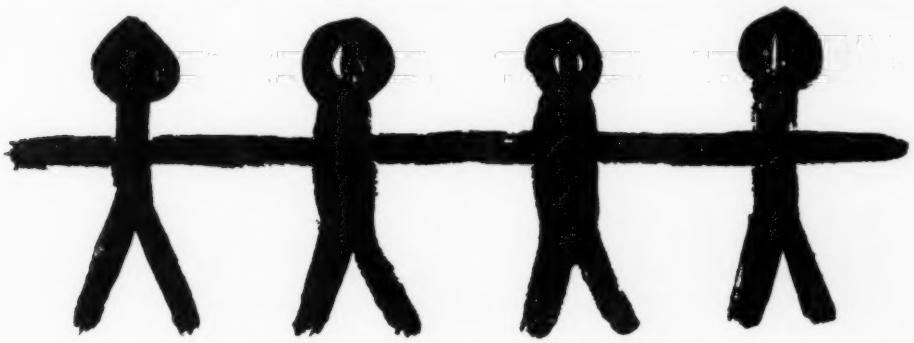

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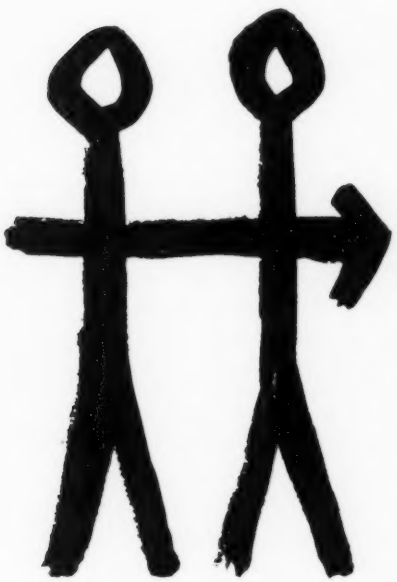

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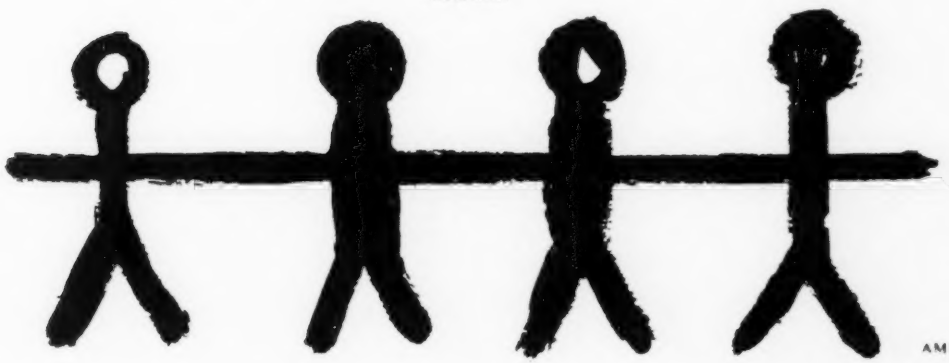

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Edited by L.J.WITTS C.B.E.

Nuffield Professor of Clinical Medicine in the University of Oxford

During the present century a new technique of clinical research has been developed which consists of the study of disease in groups instead of—as in past centuries—in individual patients. This book, which is the first to be written on this increasingly important branch of research,will prove invaluable not only to those holding full-time research appointments but also to all engaged in any branch of clinical medicine, whether as consultants or general practitioners.
The book is divided into two parts: Part I Methods and Part II Applications. The first part commences with a chapter on the general principles of group research followed by chapters on diagnosis in group research; prevalence surveys; prospective and retrospective studies; follow-up studies; prophylactic and therapeutic trials; the use of volunteers, controls, placebos, and questionnaires in clinical trials; and operational research in medicine.
The second part shows how these methods may be applied in many different branches of medical science, each chapter being illustrated by a number of relevant examples which show what has already been achieved by these methods of research, such as the elucidation of retrolental fibroplasia—soon followed by its virtual disappearance—the role of maternal rubella in the causation of foetal abnormalities, of the importance of tobacco smoking in the aetiology of cancer of the lung. No attempt has been made to include all branches of clinical medicine but those selected for detailed discussion provide ample information for workers in any other branch of medicine. Part II contains chapters on genetics, human nutrition, child development and health, chest diseases, cardiovascular diseases, diseases of joints, mental illness, cancer, and tropical diseases.
Every author has written from wide personal experience and all have made a number of distinguished contributions to medical research, many of which are used as the actual working examples that appear in the different chapters of this book.

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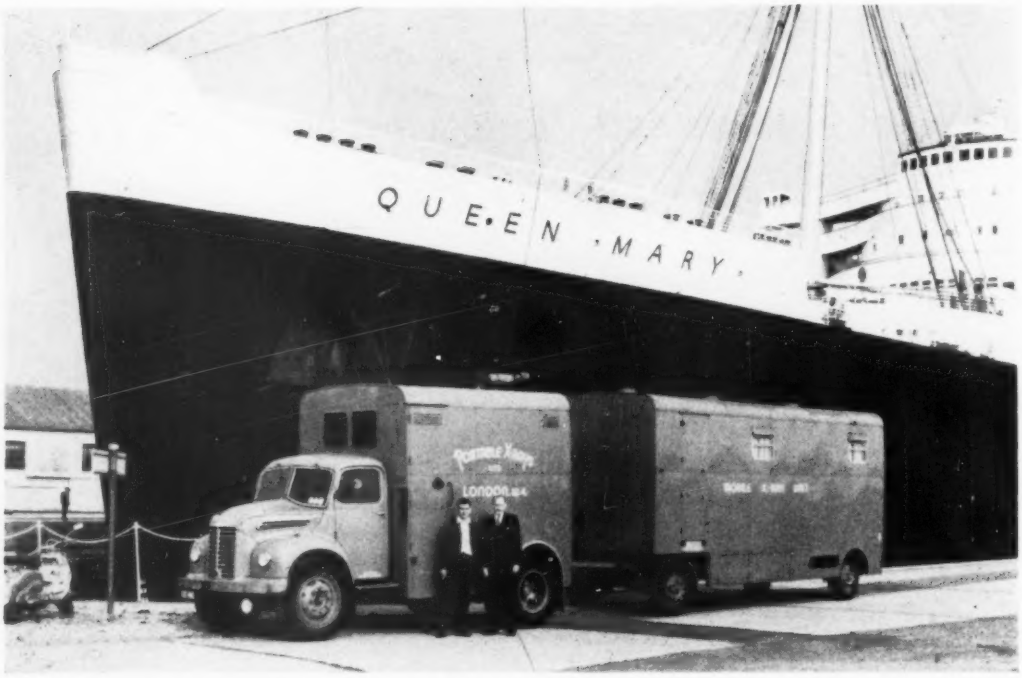

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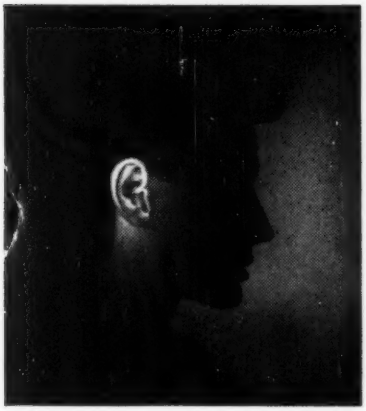

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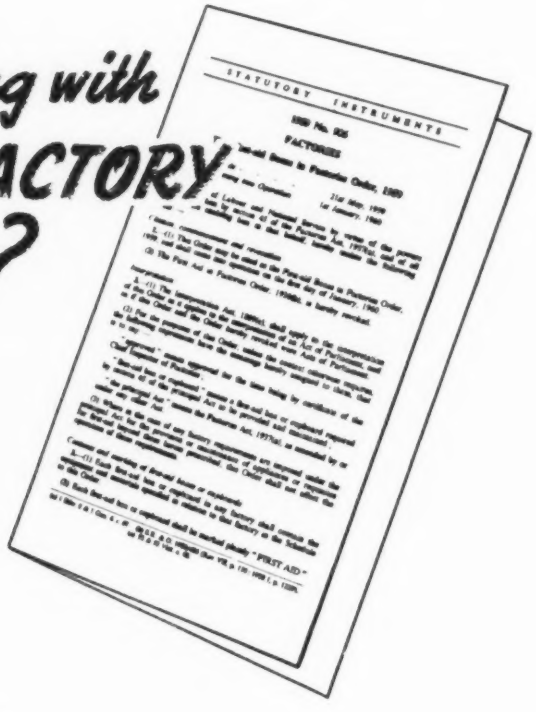

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POPULATION STUDIES OF CHRONIC RESPIRATORY DISEASE

A COMPARISON OF MINERS, FOUNDRYWORKERS, AND OTHERS IN STAVELEY, DERBYSHIRE

BY

I. T. T. HIGGINS, A. L. COCHRANE, J. C. GILSON, and C. H. WOOD

From the Pneumoconiosis Research Unit, Llandough Hospital, Nr. Penarth, Glamorgan, and the London School of Hygiene and Tropical Medicine

(RECEIVED FOR PUBLICATION APRIL 23, 1959)

Mortality and morbidity statistics suggest that miners and foundryworkers are more prone to bronchitis than other industrial workers but it is not yet certain that this excess is due to occupational factors. The present investigation was designed to compare the prevalence of bronchitis and respiratory disability in a representative sample of miners, foundryworkers, and other industrial groups living in Staveley, Derbyshire, a town of some 18,000 inhabitants, and to study some of the possible aetiological factors. A random sample of 776 men, stratified by age into two groups, 25 to 34 and 55 to 64 years, and by occupation into four groups, non-dusty, miners and ex-miners, foundry and ex-foundryworkers, and other dusty jobs, was used. Respiratory symptoms were recorded on a standardized questionnaire and the ventilatory capacity was assessed by means of the forced expiratory volume ($F.E.V._{\cdot 0.75}$) and recorded as the indirect maximum breathing capacity (M.B.C.).

Miners and ex-miners recorded a higher prevalence of respiratory symptoms and a lower mean M.B.C. than men who had worked only in dust-free occupations. In the older age group the differences were not large and were not statistically significant but in the younger men the difference in the mean M.B.C. was significant. Foundry and ex-foundryworkers with a pure industrial history recorded a similar prevalence of symptoms to the men who had never worked in dusty occupations and their mean M.B.C. was only slightly and insignificantly lower. A higher prevalence of symptoms and a lower mean M.B.C. was, however, recorded by the foundrymen who had also been exposed to other dusts or fumes and the occupational histories suggested that such exposure was more likely than foundry work to account for the findings.

The number of years spent on the coal-getting shift was used to assess the importance of exposure to coal dust. In the elderly miners without pneumoconiosis there was a significant increase in the prevalence of breathlessness, accompanied by a reciprocal fall in the mean M.B.C. with increasing years spent on the coal-getting shift; but in no other group was a consistent trend found.

In both age groups the prevalence of respiratory symptoms was lower and the mean M.B.C. higher in non-smokers than in smokers and ex-smokers. Heavy smokers (those smoking 15g. and over/day) recorded a higher prevalence of symptoms and a lower mean M.B.C. than light smokers, and the values for ex-smokers approximated to those of the non-smokers.

The wives of the elderly men in the sample were studied to try to determine how far the apparently high rates of bronchitis shown by national mortality statistics are attributable to social factors. The findings suggested that the wives of the men who worked in dusty jobs had a somewhat higher prevalence of cough and/or sputum and of chest illness during the past three years than the wives of those who had worked only in dust-free occupations.

It is difficult to assess the role of occupation in the aetiology of bronchitis. The national statistics indicate that miners and foundryworkers have an excess mortality and morbidity from bronchitis

compared with other workers and at first sight this suggests that these occupations are important factors in the development of this disease. Further contemplation of the statistics leads to considerable doubt about this apparently obvious conclusion. In both 1931 and 1951 (Registrar-General, 1938 and 1957-58) while the standardized mortality ratios (S.M.R.) for bronchitis of miners and foundryworkers was high, that of their wives was also high (Table 1), and this association is used by the Registrar-General as an argument in favour of aetiological factors other than occupation. Although the morbidity statistics (Ministry of Pensions and National Insurance, 1954), also indicate that foundrymen have approximately twice, and miners between two and three times, as much sickness absence as the national average for all occupied males, this excess might be attributed to a tendency to take time off on account of the hard manual work of their jobs since their absence rate for all causes is also high (Fletcher, 1958).

TABLE 1

STANDARDIZED MORTALITY RATIOS (S.M.R.) FOR BRONCHITIS OF MINERS AND FOUNDRYWORKERS AND THEIR WIVES IN 1931 AND 1951 (AGED 20 TO 64 YEARS. ENGLAND AND WALES)

Occupation	1931		1951	
	Men	Wives	Men	Wives
Miners (Occupational codes: 041, 042, 043 to 5, 047, and 049)	155	181	135	175
Hewers and getters (041, 042)	170	182	200	190
Other underground (043 to 5, 047)	126	162	93	177
Surface (049)	172	225	131	139
Iron and steel foundryworkers	179	288	177	217

Recent research has supported the view that miners are unduly prone to bronchitis. Böhme and Lent (1951), studying a large hospital group, found approximately twice as much bronchitis in miners as in men who had never worked in the mines. Pemberton (1956) after studying several different industrial groups in the United States concluded that miners had more "chronic bronchitis, emphysema, and bronchial spasm". Our own community surveys in the Rhondda Fach (Carpenter, Cochrane, Gilson, and Higgins, 1956) and in Leigh, Lancashire (Higgins, Oldham, Cochrane, and Gilson, 1956), have also indicated that miners and ex-miners have more bronchitis and respiratory disability than non-miners of comparable age. An unexpected finding in our studies which has not yet been adequately explained has been that disability tended to be greater in miners without pneumoconiosis than in those with early simple pneumoconiosis.

Little research has as yet been devoted specifically to studying bronchitis in foundryworkers. Previous studies in this industry (McLaughlin, Cheeseman, Garrod, Gloyne, Goodall, Harding, Jupe, Lawrie, Perry, Sutherland, and Woods, 1950; Meiklejohn, private communication) have been concerned mainly with pneumoconiosis. Apart from its inherent interest and the belief among employees that their jobs predispose them to bronchitis, we thought that an investigation of foundryworkers, who are less liable than miners to pneumoconiosis, might throw light on the problem of the disabled men whose radiographs show no evidence of pneumoconiosis. It also seemed important to try to confirm the apparent excess morbidity revealed by the national statistics and if possible to elucidate its cause.

Two approaches to the problem of bronchitis in foundryworkers are possible: a random sample of foundries might be chosen and the foundrymen working in them compared by foundry and job; or a community survey of a foundry town might be carried out on lines similar to those used previously in studying a mining town (Higgins *et al.*, 1956). There are two main disadvantages in studying a working population: exclusion of those who have retired prematurely on account of disease may lead one to underestimate disability due to occupation; the lack of a suitable control group prevents a comparison with those outside the industry living in the same neighbourhood. Such controls are essential in studying bronchitis which varies widely in prevalence from place to place. For these reasons we decided on the community survey, though we have always considered both methods desirable and indeed complementary.

The first problem was to select a suitable town. The size of the town was important. Its population should be between 15,000 and 60,000 inhabitants; larger than 60,000 would be impossible with our resources, smaller than 15,000 would be unlikely to provide sufficient foundryworkers. The proportion of foundryworkers in the total population should be high and the foundries should be reasonably typical from the point of view of type of casting and methods employed. So far as possible we wanted to avoid foundries in which considerable changes in method had taken place during the past 15 to 20 years. From information supplied by the Amalgamated Union of Foundryworkers and the local Ministry of Labour offices we reduced a large number of suggested towns to two possible ones, which we visited. Staveley in Derbyshire was finally chosen.

Staveley is an industrial town four miles to the north of Chesterfield in the centre of industrial England. It has a railway junction with large

marshalling yards on the main line from London to Sheffield. The population, predominantly working class, is about 18,000. The main industries are mining, foundrywork, chemicals, railways, and retail trade. The main industrial groups tend to live in housing estates near their work and mix relatively little. There is considerable visible atmospheric pollution from the iron and chemical works, the two collieries, and the railways.

The typical foundry processes—pattern making, preparing the moulds and cores, melting and pouring the metal, and removal of sand by "knocking out" or "stripping" and "dressing" or "fettling"—have been well described by McLaughlin *et al.* (1950). The foundries in Staveley are atypical in that sand-spun or metal-spun pipes form a high proportion of their output. These are produced by centrifugal casting, the molten metal being poured into rapidly rotating moulds. Sand moulds are used in the sand-spun process, and there is consequently a risk of pneumoconiosis; but no sand is used in the metal-spun method, which is therefore free from this risk.

A by-product plant, associated with the foundries, makes a wide variety of chemicals; among the more important from the health point of view are hydrochloric and sulphuric acids, caustic soda, and benzol. Apart from the possibility of exposure to chemical fumes, workers in this plant are liable to considerable dust exposure from the slag crusher and to both dust and heat while working on the coke ovens.

The Objects of the Investigation

The scope of the investigation, originally concerned with foundryworkers, was considerably enlarged by the wide variety of occupations represented in Staveley. The main objects were:—

(1) To compare the prevalence of respiratory symptoms and chronic bronchitis, and the ventilatory capacity in coal-miners, foundry, chemical, and railway workers with men who had worked only in dust-free occupations.

(2) To measure the prevalence of respiratory symptoms and chronic bronchitis in their wives.

(3) To assess the consistency between two doctors in recording answers to questions about respiratory symptoms and measuring the indirect maximum breathing capacity.

(4) To assess the aetiological significance of dust, tobacco smoking, and past respiratory illnesses.

The Census

We decided to study men aged 25 to 34 and 55 to 64 years. In each age group there were four main occupational groups: (1) Foundry and ex-foundry-workers and (2) miners and ex-miners (those who had worked for one year or more in foundry work or mining); (3) men who had worked in both these occupations or in either of them and also in some other dusty job (coke ovens or furnaces) or in the chemical industry, and finally (4) men who had never worked in dusty occupations.

A private census was carried out. Every house situated within the local authority boundary was visited and a member of the household interviewed. The names, addresses, dates of birth of all men aged 25 to 34 and 55 to 64 were recorded, and a note was made if such men had ever worked in mining, foundry work, or other dusty occupation. The electoral roll was used to check that all houses had been visited. An average of 40 houses was visited and details completed by each home visitor each day and the census was completed by five home visitors in one month.

The census information was recorded on cards which were arranged into the eight age and occupational groups and a sample of the appropriate number was drawn using random numbers. We wanted 100 men in each age and occupational group; but the sample of elderly miners and ex-miners was increased to 150 to allow a subdivision of these with and without pneumoconiosis. There were only 89 elderly foundry and ex-foundryworkers and we therefore used the whole population in this group. The members of the samples were then allocated randomly to the two doctors, so that comparisons between the subgroups would be unaffected by observer differences and the differences themselves fairly estimated.

Methods

(1) Full occupational and residential histories were recorded for each man.

(2) A questionnaire about respiratory symptoms (Appendix), past chest illnesses, and smoking habits was completed by the appropriate doctor who did not know to which occupational group the men belonged.

(3) The forced expiratory volume ($F.E.V._{\cdot 0\cdot 75}$) was measured and the mean of three readings after a practice blow converted to the indirect maximum breathing capacity (M.B.C.) by multiplying by 40. The forced vital capacity (F.V.C.) was also measured.

(4) Standing and sitting heights and weight were recorded to the nearest half inch and pound respectively.

(5) A postero-anterior chest radiograph was taken.

(6) While the survey of the men was taking place one of us (C.H.W.) visited the wives of the older men in their homes. The respiratory symptoms questionnaire was completed for the women and an estimate of their ventilatory capacity was obtained, using Wright's peak flowmeter (Wright and McKerrow, 1959).

TABLE 2

RANDOM SAMPLE AND RESPONSE RATE

Age Group (Years)	Occupation	Number Living in Staveley	Number Sampled	Number Seen	Number Refused
25 to 34	Non-dusty	329	100	93	7
	Miners and ex-miners (pure)	284	100	94	6
	Foundry and ex-foundryworkers (pure)	155	100	94	6
	Others	272	100	94	6
	Total	1,040	400 (100%)	375 (94%)	25 (6%)
55 to 64	Non-dusty	163	100	94	6
	Miners and ex-miners (pure)	408	150	133	17
	Foundry and ex-foundryworkers (pure)	89	89	83	6
	Others	225	100	91	9
	Total	885	439 (100%)	401 (91%)	38 (9%)

TABLE 3

DIFFERENCES BETWEEN TWO OBSERVERS IN RECORDING RESPIRATORY SYMPTOMS

Age Group (Years)	Observer	Total Seen	Persistent Cough and Sputum	Wheezing in Chest (Positive to Question 16)	Breathlessness		Chest Illness			"Chronic Bronchitis" (Sputum and Illness)
					Grades 2 and Over	Grades 3 and Over	Once	More than Once	Total	
25 to 34	J.C.G.	190 (100%)	52 (27·4%)	67 (35·3%)	22 (11·6%)	0	21 (11·1%)	7 (3·7%)	28 (14·8%)	13 (6·8%)
	I.T.T.H.	185 (100%)	40 (21·6%)	87 (47·0%)	9 (4·9%)	0	14 (7·6%)	5 (2·7%)	19 (10·3%)	13 (7·0%)
55 to 64	J.C.G.	198 (100%)	83 (41·9%)	107 (54·0%)	84 (42·4%)	25 (12·6%)	19 (9·6%)	35 (17·7%)	54 (27·3)%	43 (21·7%)
	I.T.T.H.	203 (100%)	73 (36·0%)	120 (59·1%)	77 (37·9%)	32 (15·8%)	18 (8·9%)	30 (14·8%)	48 (23·7%)	36 (17·7%)

TABLE 4

DIFFERENCES BETWEEN TWO OBSERVERS IN MEAN INDIRECT M.B.C. MEASUREMENTS

Age Group (Years)	Occupation	Observer		Difference
		J.C.G.	I.T.T.H.	
25 to 34	Non-dusty	143·9	139·7	4·2
	Miners and ex-miners	135·5	133·1	2·4
	Foundry and ex-foundryworkers	143·3	136·1	7·2
	Others	137·7	137·7	0
	All occupations	140·3	136·6	3·7
55 to 64	Non-dusty	93·4	90·2	3·2
	Miners and ex-miners	85·8	87·2	1·4
	Foundry and ex-foundryworkers	88·7	81·0	7·7
	Others	91·3	73·7	17·6
	All occupations	89·1	83·8	5·3

Response Rate.—Table 2 shows that over 92% of the men in the sample cooperated. No special attempt was made on this occasion to interview those who refused to come to the centre by visiting them in their homes, since our previous experience has been that those who refuse do not appear to differ significantly in their bronchitis experience from those who attend.

Observer Differences in Recording Symptoms and M.B.C.—The whole sample, irrespective of occupation group, has been used to investigate the differences between the two doctors in recording the answers to the questions. There were 375 young and 401 elderly men and the numbers seen by each doctor in each age group and the comparison of the main symptoms used in the analysis is shown in Table 3. A more detailed comparison of results with the questionnaire that was used is given in the Appendix.

The agreement between the observers was of course not perfect and for certain questions, notably those about colour of sputum, wheeze, and tightness, it was poor. For most questions it was in our opinion sufficiently close to justify combining the results. Differences in mean M.B.C. are shown in Table 4. Differences exceeding 5 litres/minute occurred in three out of eight of the age/occupation groups. There is no significant evidence that these variations between occupational groups are meaningful ($0{\cdot}10 > P > 0{\cdot}05$ for the men aged 25 to 34, $0{\cdot}20 > P > 0{\cdot}10$ for those aged 55 to 64) and the overall observer differences are also insignificant, though in the young men $P = 0{\cdot}074$.

TABLE 5

RECONSTITUTED GROUPS AFTER EXCLUDING WORKERS WITH INCORRECT AGES AND CORRECTING FOR OCCUPATION ERRORS

Age Group (Years)	Occupation	Number Interviewed	No. Excluded on Account of		Number Remaining	No. with Wrongly Classified Occupation			Number in Reconstituted Groups
			Age	Radiograph		Removed	Added	Net Effect	
25 to 34	Non-dusty	93	2	0	91	8	31	+23	114
	Miners and ex-miners	94	1	0	93	11	12	+ 1	94
	Foundry and ex-foundry	94	2	0	92	16	15	− 1	91
	Others	94	1	0	93	38	15	−23	70
	All occupations	375	6	0	369	73	73	0	369
55 to 64	Non-dusty	94	2	1	91	24	14	−10	81
	Miners and ex-miners	133	2	1	130	4	23	+19	149
	Foundry and ex-foundry	83	3	2	78	22	9	−13	65
	Others	91	3	0	88	21	25	+ 4	92
	All occupations	401	10	4	387	71	71	0	387

TABLE 6

CONSTITUTION OF THE "OTHERS" GROUP IN TABLE 5

Age Group (Years)	Miners and Ex-miners with Experience of Other Dusty Occupations or of Chemical Industry	Foundry and Ex-foundry-workers with Experience of Other Dusty Occupations or of Chemical Industry	Men with Experience of Both Mining and Foundry Industries	Remainder	Total
25 to 34	13	13	17	27	70
55 to 64	26	25	17	24	92

TABLE 7

MINERS AND EX-MINERS AND FOUNDRY AND EX-FOUNDRYWORKERS WITH EXPERIENCE IN OTHER DUSTY OCCUPATIONS FROM "OTHERS" GROUP ADDED TO RECONSTITUTED GROUPS*

Age Group (Years)	Occupation	No. in Reconstituted Group Already Given (Table 5)	No. in Mixed Groups to be Added*	No. Finally Analysed
25 to 34	Non-dusty	114	0	114
	Miners and ex-miners	94	13 + 17 = 30	124
	Foundry and ex-foundryworkers	91	13 + 17 = 30	121
	Others	70	Remainder: 27	27
	Total	369	87	386
55 to 64	Non-dusty	81	0	81
	Miners and ex-miners	149	26 + 17 = 43	192
	Foundry and ex-foundryworkers	65	25 + 17 = 42	107
	Others	92	Remainder: 24	24
	Total	387	109	404

*Seventeen men who had worked in both occupations were added to each occupation group in each age group.

Re-distribution of the Sample.—The initial classification of men by age and occupation was made on the basis of questions asked at the time of the census. Often this information was obtained, not from the man himself, but from a member of his family. Inevitably errors both of age and of occupational groupings were revealed when the man himself was interviewed. Men found at interview to be outside the desired age groups have been excluded, while those whose occupation was wrongly recorded at the time of the census have been re-allocated to their correct group as revealed at the interview. The sample actually interviewed and the numbers in the reconstituted groups after correcting for these census errors is shown in Table 5. Four men in the elder age group were also excluded because of their chest radiographs; two on account of cardiac failure, one because he had had a pneumonectomy for lung cancer, and one because of Category 3 simple pneumoconiosis attributed to his work on the railway. They too are shown in Table 5.

In the light of the more accurate details elicited at the interview the group "others", comprising the four classes shown in Table 6, could now be re-allocated to their appropriate occupation groups, the miners and ex-miners who had also worked in the foundry industry or other dusty jobs to the mining group, the foundry and ex-foundry workers who had also worked in mining or other dusty jobs to the foundry group. The 17 men who had worked both in mining and in the foundry industry were of course included in both occupational groups which results in an excess of 17 men in the totals of each

age group. As a result of this partition only a small number of men of the "others" group remained and these are referred to in subsequent tables as the "remainder". This re-distribution of the "others" group is shown in Table 7 in which the numbers finally analysed are shown in the last column. The mining and foundry groups could be subdivided into men who had worked only in these occupations (or "pure" miners and ex-miners and "pure" foundryworkers) and men who had worked also in other dusty jobs or the chemical industry (or "mixed" groups).

Results

Prevalence of Pneumoconiosis.—The numbers by age and radiographic category of pneumoconiosis are given in Table 8. If we consider only the pure groups, 6% of the young miners had a small amount of simple pneumoconiosis. No pneumoconiosis was noted in the young foundrymen. Thirty-six per cent of the elderly miners and 23% of the elderly foundryworkers had pneumoconiosis. Two men in the sample had early progressive massive fibrosis. One of these had worked for seven years ramming moulds and one year as a general labourer in the sand-spun pipe shop and eight years as a locomotive fireman. The other had spent six years in mining, four of them on the coalface, 11 years as a furnaceman, and 22 as an iron ore crusher. He therefore appears under both occupation groups in the table.

Prevalence of Respiratory Symptoms and Mean M.B.C. According to Occupation.—Tables 9 and 10 give the prevalence of respiratory symptoms, bronchitis, and the mean indirect M.B.C. by age in the main occupational groups. Under "chronic bronchitis", as in previous studies, we have recorded those with persistent sputum and at least one chest illness sufficiently severe to keep a man off work for at least one week during the past three years.

The effect of age is clearly seen in these two tables. The fall in the mean M.B.C. from 143 litres/minute at mean age 30 to 90 litres/minute at mean age 60 in the group of men not exposed to dust is similar to that recorded for non-miners in the Rhondda (Carpenter *et al.*, 1956). The tables also show a fairly consistent rise with age in the prevalence of respiratory symptoms and bronchitis in each occupation group. It should also be noted that whereas in the younger men the majority had experienced only one chest illness during the past three years, in the older men on the other hand recurrent attacks were more frequent.

The effect of occupation is less clear cut. The young miners recorded considerably more symptoms and bronchitis and had a significantly lower mean M.B.C. than the men not exposed to dust. A similar trend is apparent in the older miners but here differences between them and the non-dusty group are much less striking. In neither age group did miners with simple pneumoconiosis appear materially different from those without. Our findings in this respect therefore support Newell and Browne (1955), who concluded from their study of 5,117 working coal-miners in four colleries in County Durham that symptoms and disability (measured by withdrawal from coalface work to less strenuous employment) was not related to radiographic category of pneumoconiosis. The pure foundryworkers closely resembled the men not exposed to dust in their pattern of respiratory symptoms and bronchitis and recorded only an insignificantly lower mean M.B.C. On the other hand the mixed foundrymen, both young and old, had appreciably more symptoms and bronchitis and considerably lower mean M.B.C. values than the corresponding non-dusty groups. The small numbers with simple pneumoconiosis make comparisons on the basis of radiological abnormality impracticable. Our conclusion was that mining but not foundry work appeared to be associated with some increased liability to bronchitis and impairment of ventilatory capacity.

Jobs within a foundry are many and varied. In the present survey the only occupational subgroup sufficiently large for separate analysis was that of the men employed in moulding. The analysis does

TABLE 8

NUMBER OF PURE AND MIXED MINERS AND FOUNDRYWORKERS IN EACH RADIOGRAPHIC CATEGORY

Age Group (Years)		Miners and Ex-miners						Foundry and Ex-foundryworkers					
		Radiographic Category					Total	Radiographic Category					Total
		0	1	2	3	PMF		0	1	2	3	PMF	
25 to 34	Pure	89	4	1	0	0	94	91	0	0	0	0	91
	Mixed	30	0	0	0	0	30	30	0	0	0	0	30
	Total	119	4	1	0	0	124	121	0	0	0	0	121
55 to 64	Pure	96	27	22	4	0	149	50	11	2	1	1	65
	Mixed	37	2	2	1	1	43	35	4	1	1	1	42
	Total	133	29	24	5	1	192	85	15	3	2	2	107

TABLE 9

PREVALENCE OF MAIN SYMPTOMS, "CHRONIC BRONCHITIS", AND MEAN INDIRECT M.B.C. IN MEN AGED 25 TO 34 YEARS IN SAMPLE STUDIED IN STAVELEY

	Non-dusty Occupations	Miners and Ex-miners			Foundry and Ex-foundry-workers	
		Without Pneumoconiosis		With Pneumoconiosis	Without Pneumoconiosis	
		Pure	Mixed	Pure	Pure	Mixed
Number in sample	114	89	30	5	91	30
Number with:						
Persistent cough and sputum	18 (15·8%)	30 (33·7%)	11 (36·7%)	1	17 (18·7%)	13 (43·3%)
Chest illness:						
Once only	10 (8·8%)	6 (6·7%)	3 (10%)	0	8 (8·8%)	5 (16·7%)
More than once	0	7 (7·9%)	0	0	2 (2·2%)	1 (3·3%)
Total	10 (8·8%)	13 (14·6%)	3 (10%)	0	10 (11%)	6 (20%)
Breathlessness:						
Grades 2 and over	10 (8·8%)	6 (6·7%)	4 (13·3%)	0	6 (6·6%)	4 (13·3%)
Grades 3 and over	0	0	0	0	0	0
"Chronic bronchitis": (persistent sputum and chest illness)	2 (1·8%)	10 (11·2%)	1 (3·3%)	0	5 (5·5%)	4 (13·3%)
Mean indirect M.B.C.	143	133	137	150	140	137

TABLE 10

PREVALENCE OF RESPIRATORY SYMPTOMS, "CHRONIC BRONCHITIS", AND MEAN INDIRECT M.B.C. IN MEN AGED 55 TO 64 YEARS IN SAMPLE STUDIED IN STAVELEY

	Non-dusty Occupations	Miners and Ex-miners				Foundry and Ex-foundryworkers			
		Without Pneumoconiosis		With Pneumoconiosis		Without Pneumoconiosis		With Pneumoconiosis	
		Pure	Mixed	Pure	Mixed	Pure	Mixed	Pure	Mixed
Number in Sample	81	96	37	53	5	50	35	14	6
Number with:									
Persistent cough and sputum	26 (32·1%)	38 (39·6%)	16 (43·2%)	20 (37·7%)	5	15 (30%)	14 (40%)	5	5
Chest illness:									
Once only	7 (8·6%)	12 (12·5%)	2 (5·4%)	2 (3·8%)	1	4 (8%)	4 (11·4%)	0	3
More than once	10 (12·3%)	15 (15·6%)	6 (16·2%)	12 (22·6%)	2	4 (8%)	9 (25·7%)	1	2
Total	17 (21%)	27 (28·1%)	8 (21·6%)	14 (26·4%)	3	8 (16%)	13 (37·1%)	1	5
Breathlessness:									
Grades 2 and over	27 (33·3%)	31 (32·3%)	17 (45·9%)	25 (47·2)%	4	22 (44%)	18 (51·4%)	4	4
Grades 3 and over	9 (11·1%)	8 (8·3%)	6 (16·2%)	9 (17%)	1	7 (14%)	8 (22·9%)	2	1
"Chronic bronchitis": (persistent sputum and chest illness)	12 (14·8%)	18 (18·8%)	6 (16·2%)	13 (24·5%)	3	5 (10%)	10 (28·6%)	0	4
Mean indirect M.B.C.	90	87	80	87	70	85	80	82	71

P.M.F. Excluded. Duplicates Included.

TABLE 11

PREVALENCE OF RESPIRATORY SYMPTOMS AND "CHRONIC BRONCHITIS", AND MEAN INDIRECT M.B.C. IN MISCELLANEOUS OCCUPATION GROUPS SEEN IN STAVELEY (AGED 55 TO 64 YEARS)

	Chemical Workers	Coke Oven Workers	Furnacemen
Number	29	14	18
Those with:			
Persistent cough and sputum	13 (44·8%)	5 (35·7%)	8 (47·1%)
Chest illness:			
Once	2 (6·9%)	3 (21·4%)	0
More than once	10 (34·5%)	0	4 (23·5%)
Total	12 (41·4%)	3 (21·4%)	4 (23·5%)
Breathlessness:			
Grades 2 and over	16 (55·2%)	6 (42·9)%	9 (50%)
Grades 3 and over	9 (31%)	1 (7·1%)	2 (11·8%)
"Chronic bronchitis"	12 (41·4%)	2 (14·3%)	4 (23·5%)
Mean indirect M.B.C.	75	68	80

not suggest that these men had any undue liability to respiratory symptoms or bronchitis. The ventilatory capacity of the elderly moulders (89 litres/minute) was very similar to that found in the men engaged in dust-free jobs.

Among the mixed groups of miners and foundry-

workers three occupations appeared to justify separate analysis. These were chemical workers employed in the by-product plant, coke oven workers, and furnace men. The chemical workers were liable to exposure to fumes of sulphuric and hydrochloric acids, benzol acid from caustic soda baths and Table 11 shows that in the 55 to 64 age group they had an unduly high prevalence of symptoms and bronchitis and a low M.B.C. Unfortunately neither of the other two groups was sufficiently large to enable one to do more than suggest that these men might have some reduction in ventilatory capacity. It appeared to us that the higher prevalence of symptoms and lower mean M.B.C. in the mixed mining and foundry groups was more likely to be due to risk associated with one of these three occupations than to either mining or foundry work.

Tobacco Smoking.—Smoking habits were recorded after the respiratory symptoms. Unless the subject volunteered the information the doctor completing the respiratory symptoms questionnaire did not know whether he was questioning a smoker or non-smoker. Nevertheless the freedom from symptoms of the elderly non-smokers was often so striking that accurate prediction was possible. The relation of symptoms to smoking in the whole sample using the smoking classification employed previously (Doll and Hill, 1950) is given in Table 12. The findings for all occupational subgroups have been combined. Smokers recorded more symptoms than non-smokers and there is a well-marked trend of increasing cough and sputum with increasing tobacco consumption. Similarly in the case of the ventilatory capacity, the mean M.B.C. of the smokers was lower than that of the non-smokers and in both age groups the heavier smokers recorded a lower mean M.B.C. than the lighter. Perhaps the most striking observation is the considerable difference in the prevalence of cough and sputum between the non-smokers and light smokers in the 55 to 64 age group.

Dust Exposure.—We have only indirect measures of dust dosage. Two that can be used are the number of years spent underground and the number of years on the coal-getting shift and of the two the latter is clearly the better index of dust dosage. The relation of symptoms and M.B.C. to this index is given in Tables 13 and 14 for the pure miners.

In the younger age group no striking change either in prevalence of symptoms or mean M.B.C. with duration of facework was apparent. But in the older men without pneumoconiosis there was a trend in the prevalence of symptoms, best seen in the case of breathlessness, accompanied by a reciprocal fall in the mean M.B.C. with increasing years spent on the coal-getting shift. Neither effect was seen in the elderly miners with simple pneumoconiosis.

Investigation of Wives.—There were 338 wives of the elderly men in the sample, of whom 334 (99%) were seen and four refused interview. The numbers according to their husband's occupation are shown in Table 15. A much lower prevalence of cough and sputum was recorded for the wives than for their husbands. Table 16 shows the comparison of cough and/or sputum and Table 17 that of chest

TABLE 12

RELATION OF RESPIRATORY SYMPTOMS, "CHRONIC BRONCHITIS", AND INDIRECT M.B.C. TO SMOKING IN SAMPLE OF MEN STUDIED IN STAVELEY

Age Group (Years)		Non-smokers	Smokers		Ex-smokers	Total
			Light (1 to 14g./day)	Heavy (15g./day and over)		
25 to 34	Number	56	193	89	31	369
	Those with:					
	Persistent cough and sputum	5 (8·9%)	43 (22·3%)	39 (43·8%)	4 (12·9%)	91 (24·7%)
	Chest illness	4 (7·1%)	25 (13%)	11 (12·4%)	7 (22·6%)	47 (12·7%)
	Breathlessness:					
	Grades 2 and over	3 (5·4%)	17 (8·8%)	11 (12·4%)	0	31 (8·4%)
	"Chronic bronchitis"	2 (3·6%)	13 (6·7%)	7 (7·9%)	4 (12·9%)	27 (7·3%)
	Mean indirect M.B.C.	145	140	133	143	
55 to 64	Number	29	157	136	62	384*
	Those with:					
	Persistent cough and sputum	1 (3·4%)	61 (38·9%)	70 (51·5%)	13 (21%)	145 (37·8%)
	Chest illness	2 (6·9%)	41 (26·1%)	39 (28·7%)	13 (21%)	95 (24·7%)
	Breathlessness:					
	Grades 2 and over	5 (17·2%)	63 (40·1%)	62 (45·6%)	20 (32·3%)	150 (39·1%)
	"Chronic bronchitis"	1 (3·4%)	32 (20·3%)	30 (22·1%)	8 (12·9%)	71 (18·5%)
	Mean indirect M.B.C.	101	87	80	89	

* = Three exclusions (one not recorded and two P.M.F.)

TABLE 13

PREVALENCE OF RESPIRATORY SYMPTOMS AND MEAN INDIRECT M.B.C. ACCORDING TO NUMBER OF YEARS SPENT WORKING ON THE COAL-GETTING SHIFT IN MEN AGED 25 TO 34 YEARS WITHOUT PNEUMOCONIOSIS

	Years spent on Coalface			
	0	1 to 9	10 to 19	Total
All	41	38	10	89
Those with:				
Persistent cough and sputum	13 (31·7%)	17 (44·7%)	0	30 (33·7%)
Chest illness	6 (14·6%)	6 (15·8%)	1 (10%)	13 (14·6%)
Breathlessness	1 (2·4%)	5 (13·2%)	0	6 (6·7%)
"Chronic bronchitis"	5 (12·2%)	5 (13·2%)	0	10 (11·2%)
Mean indirect M.B.C.	134	133	135	133

TABLE 14

PREVALENCE OF RESPIRATORY SYMPTOMS AND MEAN INDIRECT M.B.C. ACCORDING TO NUMBER OF YEARS SPENT WORKING ON COAL-GETTING SHIFT IN MEN AGED 55 TO 64 YEARS

	Years spent on Coalface				
	0	1 to 9	10 to 19	20 and over	Total
(a) Without pneumoconiosis					
All	38	17	25	16	96
Those with:					
Persistent cough and sputum	14 (36·8%)	6 (35·3%)	11 (44%)	7 (43·8%)	38 (39·6)%
Chest illness	11 (28·9%)	3 (17·6%)	9 (36%)	4 (25%)	27 (28·1%)
Breathlessness	8 (21·1%)	5 (29·4%)	9 (36%)	9 (56·3%)	31 (32·3%)
"Chronic bronchitis"	8 (21·1%)	2 (11·8%)	5 (20%)	3 (18·8%)	18 (18·8%)
Mean indirect M.B.C.	95	89	82	74	87

	0	1 to 9	10 to 19	20 to 29	30 and over	Total
(b) With simple pneumoconiosis						
All	3	8	15	13	14	53
Those with:						
Persistent cough and sputum	1	1	7	5	6	20 (37·7%)
Chest illness	1	1	6	5	1	14 (26·4%)
Breathlessness	3	4	7	6	5	25 (47·2%)
"Chronic bronchitis"	1	1	5	5	1	13 (24·5%)
Mean indirect M.B.C.	78	96	87	88	85	87

TABLE 15

ANALYSIS OF WIVES OF ELDERLY MEN BY HUSBANDS' OCCUPATION

Occupation	No. of Men	No. of Bachelors and Widowers*	No. of Wives Seen
Non-dusty	81	15	66
Miners and ex-miners	192	26	166
Foundry and ex-foundry-workers	90†	9	81
Remainder	24	3	21
Total	387	53	334

*Including four men whose wives refused interview.

†The 17 men (see Table 7) have been allocated here to one occupation group only.

illness in the wives according to the occupation of their husbands. In each table the first column shows the number of couples and the second and third columns the prevalence of the symptoms in the men and women respectively. The tables show that the wives of the men who worked in dusty occupations recorded a higher prevalence of cough and/or sputum and chest illness than did the wives of the men who had worked only in dust-free jobs. In the case of chest illness the difference does not quite reach the 5% level of significance. The last two columns show the prevalence of symptoms in the wives according to whether their husbands had or were free from the symptom. They show that the prevalence of both cough and/or sputum and of chest illness was slightly higher in the wives of the men with those symptoms but in neither case does the difference reach the 5% level of significance.

TABLE 16

PREVALENCE OF PERSISTENT COUGH AND/OR SPUTUM IN MEN AGED 55 TO 64 YEARS AND THEIR WIVES, ACCORDING TO OCCUPATION

Occupation	No. of Couples	Husbands Positive	Wives Positive	Husbands and Wives Positive	Husbands Negative with Wives Positive
Miners and ex-miners	166	102 (61·4%)	42 (25·3%)	29 (28·4%)	13 (20·3%)
Foundry and ex-foundryworkers	81	44 (54·3%)	18 (22·2%)	9 (20·5%)	9 (24·3%)
Remainder	21	13 (61·9%)	5 (23·8%)	5 (38·5%)	0
Total dusty	268	159 (59·3%)	65 (24·3%)	43 (27%)	22 (20·2%)
Non-dusty	66	27 (40·9%)	10 (15·2%)	4 (14·8%)	6 (15·4%)
Total	334	186 (55·7%)	75 (22·5%)	47 (25·3%)	28 (18·9%)

TABLE 17

PREVALENCE OF CHEST ILLNESSES (ONE OR MORE IN PAST THREE YEARS) IN MEN AGED 55 TO 64 YEARS AND THEIR WIVES, ACCORDING TO OCCUPATION

the mixed mining and foundry groups was more likely to be due to risk associated with one of these three occupations than to either mining or foundry work.

Tobacco Smoking.—Smoking habits were recorded after the respiratory symptoms. Unless the subject volunteered the information the doctor completing the respiratory symptoms questionnaire did not know whether he was questioning a smoker or non-smoker. Nevertheless the freedom from symptoms of the elderly non-smokers was often so striking that accurate prediction was possible. The relation of symptoms to smoking in the whole sample using the smoking classification employed previously (Doll and Hill, 1950) is given in Table 12. The findings for all occupational subgroups have been combined. Smokers recorded more symptoms than non-smokers and there is a well-marked trend of increasing cough and sputum with increasing tobacco consumption. Similarly in the case of the of symptoms and M.B.C. to this index is given in Tables 13 and 14 for the pure miners.

In the younger age group no striking change either in prevalence of symptoms or mean M.B.C. with duration of facework was apparent. But in the older men without pneumoconiosis there was a trend in the prevalence of symptoms, best seen in the case of breathlessness, accompanied by a reciprocal fall in the mean M.B.C. with increasing years spent on the coal-getting shift. Neither effect was seen in the elderly miners with simple pneumoconiosis.

Investigation of Wives.—There were 338 wives of the elderly men in the sample, of whom 334 (99%) were seen and four refused interview. The numbers according to their husband's occupation are shown in Table 15. A much lower prevalence of cough and sputum was recorded for the wives than for their husbands. Table 16 shows the comparison of cough and/or sputum and Table 17 that of chest

TABLE 12

RELATION OF RESPIRATORY SYMPTOMS, "CHRONIC BRONCHITIS", AND INDIRECT M.B.C. TO SMOKING IN SAMPLE OF MEN STUDIED IN STAVELEY

Age Group (Years)		Non-smokers	Smokers		Ex-smokers	Total
			Light (1 to 14g./day)	Heavy (15g./day and over)		
25 to 34	Number	56	193	89	31	369
	Those with:					
	Persistent cough and sputum	5 (8·9%)	43 (22·3%)	39 (43·8%)	4 (12·9%)	91 (24·7%)
	Chest illness	4 (7·1%)	25 (13%)	11 (12·4%)	7 (22·6%)	47 (12·7%)
	Breathlessness:					
	Grades 2 and over	3 (5·4%)	17 (8·8%)	11 (12·4%)	0	31 (8·4%)
	"Chronic bronchitis"	2 (3·6%)	13 (6·7%)	7 (7·9%)	4 (12·9%)	27 (7·3%)
	Mean indirect M.B.C.	145	140	133	143	
55 to 64	Number	29	157	136	62	384*
	Those with:					
	Persistent cough and sputum	1 (3·4%)	61 (38·9%)	70 (51·5%)	13 (21%)	145 (37·8%)
	Chest illness	2 (6·9%)	41 (26·1%)	39 (28·7%)	13 (21%)	95 (24·7%)
	Breathlessness:					
	Grades 2 and over	5 (17·2%)	63 (40·1%)	62 (45·6%)	20 (32·3%)	150 (39·1%)
	"Chronic bronchitis"	1 (3·4%)	32 (20·3%)	30 (22·1%)	8 (12·9%)	71 (18·5%)
	Mean indirect M.B.C.	101	87	80	89	

* —Three exclusions (one not recorded and two P.M.F.)

Aetiology of Bronchitis.—Of the various factors—age, sex, infection, allergy, social circumstances, familial susceptibility, occupation, exposure to dusts, atmospheric pollution, and tobacco smoking—considered to be important in the aetiology of bronchitis, the present discussion will be limited mainly to the last four.

The Influence of Occupation.—This was studied in mine and foundryworkers and in certain chemical workers.

Miners.—We believed before we went to Staveley that mining was associated with an increased liability to chronic non-specific respiratory disease. We expected that the higher prevalence of symptoms

TABLE 18

STANDARDIZED MORTALITY RATIOS (S.M.R.) OF MINERS AGED 20 TO 64 YEARS, FOR BRONCHITIS IN DIFFERENT MINING AREAS IN 1951 (REGISTRAR-GENERAL, 1958)

Area	Registered Deaths	Expected Deaths	S.M.R.
Brecknockshire, Carmarthen, Pembrokeshire (anthracite)	21	17	124
Brecknockshire and Carmarthenshire (remainder)	17	9	190
Glamorgan (anthracite)	33	13	254
Glamorgan (remainder)	261	127	207
Monmouthshire	99	56	177
Cumberland	7	9	78
Durham	217	196	111
Northumberland	98	77	127
Yorkshire, West Riding	309	231	134
Cheshire and Lancashire	132	90	147
Derbyshire (except South Derbyshire)	56	70	80
Leicestershire, Warwickshire, and South Derbyshire	48	52	92
Nottinghamshire	83	73	114

SPENT WORKING ON COAL-GETTING SHIFT (IN MEN AGED [illegible])

	Years spent on Coalface				
	0	1 to 9	10 to 19	20 and over	Total
(a) Without pneumoconiosis					
All	38	17	25	16	96
Those with:					
Persistent cough and sputum	14 (36·8%)	6 (35·3%)	11 (44%)	7 (43·8%)	38 (39·6)%
Chest illness	11 (28·9%)	3 (17·6%)	9 (36%)	4 (25%)	27 (28·1%)
Breathlessness	8 (21·1%)	5 (29·4%)	9 (36%)	9 (56·3%)	31 (32·3%)
"Chronic bronchitis"	8 (21·1%)	2 (11·8%)	5 (20%)	3 (18·8%)	18 (18·8%)
Mean indirect M.B.C.	95	89	82	74	87

	0	1 to 9	10 to 19	20 to 29	30 and over	Total
(b) With simple pneumoconiosis						
All	3	8	15	13	14	53
Those with:						
Persistent cough and sputum	1	1	7	5	6	20 (37·7%)
Chest illness	1	1	6	5	1	14 (26·4%)
Breathlessness	3	4	7	6	5	25 (47·2%)
"Chronic bronchitis"	1	1	5	5	1	13 (24·5%)
Mean indirect M.B.C.	78	96	87	88	85	87

TABLE 15

ANALYSIS OF WIVES OF ELDERLY MEN BY HUSBANDS' OCCUPATION

Occupation	No. of Men	No. of Bachelors and Widowers*	No. of Wives Seen
Non-dusty	81	15	66
Miners and ex-miners	192	26	166
Foundry and ex-foundry-workers	90†	9	81
Remainder	24	3	21
Total	387	53	334

*Including four men whose wives refused interview.

†The 17 men (see Table 7) have been allocated here to one occupation group only.

illness in the wives according to the occupation of their husbands. In each table the first column shows the number of couples and the second and third columns the prevalence of the symptoms in the men and women respectively. The tables show that the wives of the men who worked in dusty occupations recorded a higher prevalence of cough and/or sputum and chest illness than did the wives of the men who had worked only in dust-free jobs. In the case of chest illness the difference does not quite reach the 5% level of significance. The last two columns show the prevalence of symptoms in the wives according to whether their husbands had or were free from the symptom. They show that the prevalence of both cough and/or sputum and of chest illness was slightly higher in the wives of the men with those symptoms but in neither case does the difference reach the 5% level of significance.

TABLE 16

PREVALENCE OF PERSISTENT COUGH AND/OR SPUTUM IN MEN AGED 55 TO 64 YEARS AND THEIR WIVES, ACCORDING TO OCCUPATION

Occupation	No. of Couples	Husbands Positive	Wives Positive	Husbands and Wives Positive	Husbands Negative with Wives Positive
Miners and ex-miners	166	102 (61·4%)	42 (25·3%)	29 (28·4%)	13 (20·3%)
Foundry and ex-foundryworkers	81	44 (54·3%)	18 (22·2%)	9 (20·5%)	9 (24·3%)
Remainder	21	13 (61·9%)	5 (23·8%)	5 (38·5%)	0
Total dusty	268	159 (59·3%)	65 (24·3%)	43 (27%)	22 (20·2%)
Non-dusty	66	27 (40·9%)	10 (15·2%)	4 (14·8%)	6 (15·4%)
Total	334	186 (55·7%)	75 (22·5%)	47 (25·3%)	28 (18·9%)

TABLE 17

PREVALENCE OF CHEST ILLNESSES (ONE OR MORE IN PAST THREE YEARS) IN MEN AGED 55 TO 64 YEARS AND THEIR WIVES, ACCORDING TO OCCUPATION

Occupation	No. of Couples	Husbands Positive	Wives Positive	Husbands and Wives Positive	Husbands Negative with Wives Positive
Miners and ex-miners	166	46 (27·7%)	35 (21·1%)	11 (23·9%)	24 (20%)
Foundry and ex-foundryworkers	81	20 (24·7%)	14 (17·3%)	3 (15%)	11 (18%)
Remainder	21	4 (19%)	5 (23·8%)	1(25%)	4 (23·5%)
Total dusty	268	70 (26·1%)	54 (20·1%)	15 (21·4%)	39 (19·7%)
Non-dusty	66	13 (19·7%)	6 (9·1%)	3 (23·1%)	3 (5·7%)
Total	334	83 (24·9%)	60 (18%)	18 (21·7%)	42 (16·7%)

Discussion

Methodology.—Instead of establishing the population of Staveley by means of a private census we might have sampled from the electoral roll using a method similar to that employed in our survey in Leigh (Higgins *et al.*, 1956). The practicability of such a method in the present survey turned on the number of foundryworkers living in Staveley. From the information available we predicted that this number would be so small that we should have to visit over half the houses in the town. Rather than visit at random until the required number of foundryworkers had been obtained we decided that it would be quicker to visit every house systematically. In fact only 89 elderly foundry and ex-foundryworkers were encountered in the whole town and we should therefore have had to visit all the houses in either case.

The preliminary information about age and occupation necessary for drawing a stratified sample might have been obtained by means of a postal census. We considered this method but rejected it because we had no idea what sort of response we could expect. Since then Gray (1957) has reported a response rate of over 90% to postal enquiry and a postal census might certainly be attempted in future surveys.

The most accurate way to obtain a random sample of the population of a particular community, stratified for age and for occupation, is to interview all the potential members of the sample personally, accepting no secondhand information. This was the procedure employed in the Rhondda Fach and Vale of Glamorgan (Cochrane, Cox, and Jarman, 1952, 1955; Cochrane, Miall, and Clarke, 1956) and in Annandale (Cochran, Clayson, and Fletcher, 1957). In each case an occupational history was obtained from every man when he attended for chest radiography. In the present investigation census information about men in the two age groups was often obtained from a near relative. To have insisted on seeing each man individually would, we felt, have prolonged the census unjustifiably. Errors were inevitably introduced into the provisional age and occupational groups which we sampled. Correction of these inaccuracies complicated the subsequent treatment of the sample but there was in fact little difference in our finding in the uncorrected and corrected samples.

We have mentioned the theoretical justification for trying to assess chronic respiratory disease in the community rather than in a working population of foundrymen. The present survey indicates the practical limitations to this approach. Our preliminary enquiries suggested that in no town in the country other than Staveley would this method have been possible. Even in Staveley there were fewer elderly pure foundry and ex-foundryworkers than we really needed. There were certainly insufficient to study the various occupational groups within the industry, adequate numbers for which could only be obtained by studying a working population.

Aetiology of Bronchitis.—Of the various factors—age, sex, infection, allergy, social circumstances, familial susceptibility, occupation, exposure to dusts, atmospheric pollution, and tobacco smoking—considered to be important in the aetiology of bronchitis, the present discussion will be limited mainly to the last four.

The Influence of Occupation.—This was studied in mine and foundryworkers and in certain chemical workers.

MINING.—We believed before we went to Staveley that mining was associated with an increased liability to chronic non-specific respiratory disease. We expected that the higher prevalence of symptoms and reduced ventilatory capacity observed in miners when compared with non-miners in the Rhondda and in Leigh (Carpenter *et al.*, 1956; Higgins *et al.*, 1956) would again be found in Staveley. But this generalization from our two earlier surveys was not justified. In Staveley the elderly miners and ex-miners were not strikingly different from the men who had never worked in dusty occupations, judged either on their prevalence of respiratory symptoms or on their mean M.B.C. The findings in the 25 to 34 age group were certainly more in line with our previous findings in the Rhondda Fach, the miners appearing appreciably less fit than the non-dusty group. It is difficult to see why the young miners but not the old should be disabled. One possibility is that by separating miners into pure and mixed groups we may have underestimated the amount of disease in the elderly group. Symptomatically the differences are not striking but the mixed groups, both with and without pneumoconiosis, did record a lower mean M.B.C. than the pure groups. Even when the two groups are combined the resulting M.B.C. does not suggest that the elderly miners in Staveley were particularly disabled. Another possibility is that the young miners are affected by some factor that does not affect the older men. One might postulate that they are more likely to be affected by any increase in dustiness due to recent mechanization since more will be working on the coalface. It is also possible that occupational selection during and immediately after the war of the less fit members of the community into mining may have occurred.

Differential migration (Cochrane, 1958) may possibly account for some of the regional difference between miners and ex-miners. The Rhondda was much more affected than Staveley by the depression in the inter-war years and to the extent that the healthier members may have left the community we may now be dealing with a survivor population.

The regional standardized mortality ratios (S.M.R.) for working miners for bronchitis in the different coalfields (Table 18) lend some support to the view that mining may be less injurious to health in Staveley than in other areas. Only in the central Midlands (Derbyshire, Leicestershire, and Warwickshire) and Cumberland are the S.M.R.s less than 100.

TABLE 18

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Area	Registered Deaths	Expected Deaths	S.M.R.
Brecknockshire, Carmarthen, Pembrokeshire (anthracite)	21	17	124
Brecknockshire and Carmarthenshire (remainder)	17	5	340
Glamorgan (anthracite)	33	13	254
Glamorgan (remainder)	263	127	207
Monmouthshire	99	56	177
Cumberland	7	9	78
Durham	217	196	111
Northumberland	98	77	127
Yorkshire, West Riding	309	231	134
Cheshire and Lancashire	132	90	147
Derbyshire (except South Derbyshire)	56	70	80
Leicestershire, Warwickshire, and South Derbyshire	48	52	92
Nottinghamshire	83	73	114
North Staffordshire	33	28	118
Staffordshire (remainder), Shropshire, and Worcestershire	57	46	124
Kent	12	10	120
Gloucestershire and Somerset	26	15	173
Remainder, *i.e.*, Pembrokeshire (remainder) and all other counties	29	20	145

FOUNDRY WORK.—In neither of the two age groups did the pure foundryworkers appear to have a higher prevalence of respiratory symptoms and bronchitis or a lower ventilatory capacity than the men in non-dusty occupations. On the other hand, the group of mixed foundryworkers did appear materially worse on both counts. The problem of whether their foundry experience was responsible for their excess of symptoms and disability or whether exposure to other dust or fume, in mining, chemicals, or on the coke ovens, was more important is obviously difficult. It seemed to us that the latter explanation was more probably correct.

MISCELLANEOUS OCCUPATIONS.—One of the most interesting chance observations in this survey was the high prevalence of disease and low ventilatory capacity in the chemical workers. National statistics do not suggest that men engaged in the chemical industry are unduly subject to bronchitis but the national figures include widely varying groups of workers. Further study of men exposed to certain chemicals certainly seems indicated from our limited experience. It is interesting that 38 (9%) of the men aged 55 to 64 in our sample said that they had been exposed to poison gas in the first world war. Their mean M.B.C. was 68 litres/min., which is strikingly below the average for the group.

The Influence of Dust Exposure.—The figures for symptoms according to the number of years spent

TABLE 19

PREVALENCE OF RESPIRATORY SYMPTOMS AND "CHRONIC BRONCHITIS", AND MEAN INDIRECT M.B.C. IN NON-MINERS AGED 55 TO 64 YEARS IN FOUR RANDOM SAMPLES

Sample	Rural		Urban	
	Annandale	Vale of Glamorgan	Leigh	Staveley
Number in sample	87	86	84	81
Number with:				
Persistent cough and sputum	17 (19·5%)	22 (25·6%)	15 (17·9%)	26 (32·1%)
Chest illness:				
Once	12 (13·8%)	10 (11·6%)	6 (7·1%)	7 (8·6%)
More than once	4 (4·6%)	4 (4·7%)	11 (13·1%)	10 (12·3%)
Total	16 (18·4%)	14 (16·3%)	17 (20·2%)	17 (21%)
Breathlessness:				
Grades 2 and over	25 (28·7%)	21 (24·4%)	19 (22·6%)	27 (33·3%)
"Chronic bronchitis"	6 (6·9%)	5 (5·8%)	9 (10·7%)	12 (14·8%)
Mean indirect M.B.C.	95	89	85	90

on the coal-getting shift do not suggest that the total quantity of coal dust played a very large part in the development of symptoms. It is possible that selection may occur whereby those who are affected by the coal dust tend to leave the face to work in less dusty parts of the mine. This could conceal any association between dust and respiratory symptoms.

Perhaps the most convincing evidence for an injurious effect of coal dust was the progressive fall in the mean M.B.C. accompanied by a reciprocal rise in the prevalence of breathlessness with increasing years spent on the coal-getting shift observed in the elderly miners without pneumoconiosis. These M.B.C. changes, which we were unable to show either in miners with pneumoconiosis or in the younger men, were similar to previous findings in the Rhondda and Leigh and are fully discussed elsewhere (Cochrane *et al.*, in the press). They may be compared with the observations on working coal-miners in Czechoslovakia of Kadlec and Vyskocil (1950), who showed a reduction in mean ventilatory capacity with increasing dust exposure for miners both with and without pneumoconiosis. A decline in lung function independent of age with increasing time spent working underground was also noted in a group of German miners studied by Carstens, Brinkmann, Lange, Meisterernst, and Schlicht (1958). These men were, however, seen in the course of hospital practice and it is impossible to say how much selection was therefore involved.

Effect of Tobacco Smoking.—The importance of tobacco smoking in the aetiology of bronchitis has been stressed by many authorities (Oswald and Medvei, 1955; Pemberton and Macleod, 1956; Phillips, Phillips, and Thompson, 1956; Ogilvie and Newell, 1957; Brown, McKeown, and Whitfield, 1957) and has been considered in earlier papers from this Unit (Higgins, 1959). The results in the present survey entirely support our previous conclusions that smoking is associated with an increase in respiratory symptoms and a reduction in ventilatory capacity. So important is the influence of tobacco smoking that it is essential to allow for differences in smoking in comparable groups before drawing conclusions about the importance of other factors.

Atmospheric Pollution.—Our studies of random samples in areas of widely differing pollution enable us to evaluate the possible effect of long sustained atmospheric pollution on respiratory health. Table 19 summarizes the results in four areas, two rural and two urban, for the men aged 55 to 64 years. No striking difference between town and country was observed in the prevalence of persistent cough and sputum or breathlessness; but the proportion of recurrent chest illnesses was higher in the two towns and this is reflected in a higher bronchitis rate. The mean M.B.C. was significantly lower in Leigh, the most polluted area, than in the two unpolluted rural areas, but in Staveley where pollution was also high the M.B.C. is the same as in the rural areas.

In a survey of this kind it is clearly impossible to mention everyone who has contributed to its success. We should, however, like to thank Dr. A. I. G. McLaughlin of the Medical Research Council's Department for Research in Industrial Medicine and Mr. J. Gardner, General Secretary of the Amalgamated Union of Foundry workers, for much helpful information about the foundry industry. We are indebted to our colleagues at the Pneumoconiosis Research Unit for their advice and criticism, to the radiographic and epidemiological teams, and especially to Mr. P. D. Oldham for statistical assistance.

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APPENDIX

Respiratory Symptoms Questionnaire

Name..... Sex..... Date of birth.....
Adress..... Date of questionnaire.....
..... Serial No..... Observer.....

Cough

1. Do you usually have a cough? Yes/No
   Do you cough at all on getting up or first thing in the morning?
2. Only in the winter? Yes/No
3. Or throughout the year? Yes/No
   Do you go on coughing during the day (night)?
4. Only in the winter? Yes/No
5. Or throughout the year? Yes/No

Phlegm

6. Do you usually bring up phlegm from your chest? (Not from back of nose) Yes/No
   Do you bring up any phlegm at all on getting up or first thing in the morning?
7. Only in the winter? Yes/No
8. Or throughout the year? Yes/No
   If yes, do you go on bringing it up during the day (or night)?
9. Only in the winter? Yes/No
10. Or throughout the year? Yes/No
    Is this phlegm:
11. Always clear, white, gray or blackish? Yes/No
12. Occasionally yellow or green at least in parts? Yes/No
13. Usually yellow or green? Yes/No
14. How long have you had this cough/phlegm? ☐
15. Have you ever coughed up any blood? Yes/No

Wheezing

16. Does your breathing ever sound wheezy or whistling? Yes/No
    If yes:
17. Occasionally (for example when you have a cold)? Yes/No
18. Most days (or nights)? Yes/No

Tightness

19. Does your chest ever feel tight? Yes/No
    If yes:
20. Occasionally? Yes/No
21. Most days (or nights)? Yes/No

Chest Illnesses

22. During the past three years have you had a chest illness which has kept you in bed, off work, or indoors at home? Yes/No
23. (Check: Not even 'flu) ☐
    Number of illnesses

Doctor's Diagnosis	Year	Duration (Days)	Increased Cough	Increased Phlegm	Yellow Phlegm

Previous Illnesses

Have you ever had:

	Date	
24. Pneumonia	.....	Yes/No
25. Pleurisy	.....	Yes/No
26. Bronchitis	.....	Yes/No
27. Asthma	.....	Yes/No
28. Tuberculosis	.....	Yes/No
29. Heart trouble	.....	Yes/No

30. If relevant, were you gassed in the first world war? Yes/No
31. Were you laid up with it? Yes/No
    Type of gas?.....

Breathlessness

33. Is your breathing as good as that of other people of your age at work, on hurrying, climbing hills or stairs? ☐
34. Can you keep up with people of your own age on the level without shortness of breath? ☐
35. Can you walk a mile (or ½ an hour) on the level at your own pace without stopping for breath? ☐
36. Do you have to stop after about 100 yards on the level because of breathlessness? ☐

TABLE 19

PREVALENCE OF RESPIRATORY SYMPTOMS AND "CHRONIC BRONCHITIS", AND MEAN INDIRECT M.B.C. IN NON-MINERS AGED 55 TO 64 YEARS IN FOUR RANDOM SAMPLES

Sample	Rural		Urban	
	Annandale	Vale of Glamorgan	Leigh	Staveley
Number in sample	87	86	84	81
Number with:				
Persistent cough and sputum	17 (19·5%)	22 (25·6%)	15 (17·9%)	26 (32·1%)
Chest illness:				
Once	12 (13·8%)	10 (11·6%)	6 (7·1%)	7 (8·6%)
More than once	4 (4·6%)	4 (4·7%)	11 (13·1%)	10 (12·3%)
Total	16 (18·4%)	14 (16·3%)	17 (20·2%)	17 (21%)
Breathlessness:				
Grades 2 and over	25 (28·7%)	21 (24·4%)	19 (22·6%)	27 (33·3%)
"Chronic bronchitis"	6 (6·9%)	5 (5·8%)	9 (10·7%)	12 (14·8%)
Mean indirect M.B.C.	95	89	85	90

on the coal-getting shift do not suggest that the total quantity of coal dust played a very large part in the development of symptoms. It is possible that selection may occur whereby those who are affected by the coal dust tend to leave the face to work in less dusty parts of the mine. This could conceal any association between dust and respiratory symptoms.

Perhaps the most convincing evidence for an injurious effect of coal dust was the progressive fall in the mean M.B.C. accompanied by a reciprocal rise in the prevalence of breathlessness with increasing years spent on the coal-getting shift observed in the elderly miners without pneumoconiosis. These M.B.C. changes, which we were unable to show either in miners with pneumoconiosis or in the younger men, were similar to previous findings in the Rhondda and Leigh and are fully discussed elsewhere (Cochrane *et al.*, in the press). They may be compared with the observations on working coal-miners in Czechoslovakia of Kadlec and Vyskocil (1950), who showed a reduction in mean ventilatory capacity with increasing dust exposure for miners both with and without pneumoconiosis. A decline in lung function independent of age with increasing time spent working underground was also noted in a group of German miners studied by Carstens, Brinkmann, Lange, Meisterernst, and Schlicht (1958). These men were, however, seen in the course of hospital practice and it is impossible to say how much selection was therefore involved.

Effect of Tobacco Smoking.—The importance of tobacco smoking in the aetiology of bronchitis has been stressed by many authorities (Oswald and Medvei, 1955; Pemberton and Macleod, 1956; Phillips, Phillips, and Thompson, 1956; Ogilvie and Newell, 1957; Brown, McKeown, and Whitfield, 1957) and has been considered in earlier papers from this Unit (Higgins, 1959). The results in the present survey entirely support our previous conclusions that smoking is associated with an increase in respiratory symptoms and a reduction in ventilatory capacity. So important is the influence of tobacco smoking that it is essential to allow for differences in smoking in comparable groups before drawing conclusions about the importance of other factors.

Atmospheric Pollution.—Our studies of random samples in areas of widely differing pollution enable us to evaluate the possible effect of long sustained atmospheric pollution on respiratory health. Table 19 summarizes the results in four areas, two rural and two urban, for the men aged 55 to 64 years. No striking difference between town and country was observed in the prevalence of persistent cough and sputum or breathlessness; but the proportion of recurrent chest illnesses was higher in the two towns and this is reflected in a higher bronchitis rate. The mean M.B.C. was significantly lower in Leigh, the most polluted area, than in the two unpolluted rural areas, but in Staveley where pollution was also high the M.B.C. is the same as in the rural areas.

In a survey of this kind it is clearly impossible to mention everyone who has contributed to its success. We should, however, like to thank Dr. A. I. G. McLaughlin of the Medical Research Council's Department for Research in Industrial Medicine and Mr. J. Gardner, General Secretary of the Amalgamated Union of Foundry workers, for much helpful information about the foundry industry. We are indebted to our colleagues at the Pneumoconiosis Research Unit for their advice and criticism, to the radiographic and epidemiological teams, and especially to Mr. P. D. Oldham for statistical assistance.

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APPENDIX

Respiratory Symptoms Questionnaire

Name..... Sex..... Date of birth.....
Adress..... Date of questionnaire.....
..... Serial No..... Observer.....

Cough

1. Do you usually have a cough? Yes/No
   Do you cough at all on getting up or first thing in the morning?
2. Only in the winter? Yes/No
3. Or throughout the year? Yes/No
   Do you go on coughing during the day (night)?
4. Only in the winter? Yes/No
5. Or throughout the year? Yes/No

Phlegm

6. Do you usually bring up phlegm from your chest? (Not from back of nose) Yes/No
   Do you bring up any phlegm at all on getting up or first thing in the morning?
7. Only in the winter? Yes/No
8. Or throughout the year? Yes/No
   If yes, do you go on bringing it up during the day (or night)?
9. Only in the winter? Yes/No
10. Or throughout the year? Yes/No
    Is this phlegm:
11. Always clear, white, gray or blackish? Yes/No
12. Occasionally yellow or green at least in parts? Yes/No
13. Usually yellow or green? Yes/No
14. How long have you had this cough/phlegm? ☐☐
15. Have you ever coughed up any blood? Yes/No

Wheezing

16. Does your breathing ever sound wheezy or whistling? Yes/No
    If yes:
17. Occasionally (for example when you have a cold)? Yes/No
18. Most days (or nights)? Yes/No

Tightness

19. Does your chest ever feel tight? Yes/No
    If yes:
20. Occasionally? Yes/No
21. Most days (or nights)? Yes/No

Chest Illnesses

22. During the past three years have you had a chest illness which has kept you in bed, off work, or indoors at home? Yes/No
23. (Check: Not even 'flu)
    Number of illnesses ☐

Doctor's Diagnosis	Year	Duration (Days)	Increased Cough	Increased Phlegm	Yellow Phlegm

Previous Illnesses

Have you ever had:

		Date	
24.	Pneumonia.....		Yes/No
25.	Pleurisy		Yes/No
26.	Bronchitis		Yes/No
27.	Asthma		Yes/No
28.	Tuberculosis		Yes/No
29.	Heart trouble.....		Yes/No

30. If relevant, were you gassed in the first world war? Yes/No
31. Were you laid up with it? Yes/No
    Type of gas?.....

Breathlessness

33. Is your breathing as good as that of other people of your age at work, on hurrying, climbing hills or stairs? ☐☐
34. Can you keep up with people of your own age on the level without shortness of breath? ☐☐
35. Can you walk a mile (or ½ an hour) on the level at your own pace without stopping for breath? ☐☐
36. Do you have to stop after about 100 yards on the level because of breathlessness? ☐☐

37. Are you breathless on talking, after dressing or at rest? ☐

Weather

38. Does the weather affect your chest? Yes/No
39. What sort of weather?
    Fog Damp Cold Other
40. In what way?
    Increase of cough/sputum
    Wheeze Dyspnoea Other

Colds

41. How many colds do you have each year? ☐
42. Do colds usually go to your chest? Yes/No
43. Do you get bouts of cough and phlegm for 3 weeks in winter Yes/No

Conclusion

44. Does observer consider subject to be bronchitic? Yes/No

Smoking

45. Do you smoke? Yes/No
46. If no, have you ever smoked? (Record "No" if less than one per day for a year) Yes/No
47. If yes:

	Now	Changes since 1940
Cigarettes per day	.....	.....
Oz. tobacco/week (hand rolled)	.....	.....
Oz. tobacco/week (pipe)	.....	.....
Cigars (No./week)	.....	.....
Age of starting regular smoking	.....	
Age of stopping regular smoking	.....	

If relevant:

48. Did you stop smoking because of your chest? Yes/No

APPENDIX TABLE

OBSERVER DIFFERENCES IN RECORDING RESPIRATORY SYMPTOMS

		Aged 25 to 34				Aged 55 to 64			
		Interviewed by J.C.G.		Interviewed by I.T.T.H.		Interviewed by J.C.G.		Interviewed by I.T.T.H.	
		No.	%	No.	%	No.	%	No.	%
Question No.	Total No. Seen	190	100·0	185	100·0	198	100·0	203	100·0
1	Cough	63	33·2	49	26·5	98	49·5	95	46·8
2		48	25·3	42	22·7	90	45·5	87	42·9
3		39	20·5	38	20·5	77	38·9	79	38·9
4		27	14·2	24	13·0	40*	20·2	60	29·6
5		24	12·6	22	11·9	34†	17·2	56	27·6
6	Sputum	83	43·7	67	36·2	101	51·0	88	43·3
7		53	27·9	49	26·5	87	43·9	83	40·9
8		46	24·2	46	24·9	68	34·3	78	38·4
9		50	26·3	42	22·7	55	27·8	55	27·1
10		48	25·3	41	22·2	48	24·2	54	26·6
	Cough and sputum	52	27·4	40	21·6	83	41·9	73	36·0
11	Colour	60‡	31·6	32‡	17·3	82†	41·4	60†	29·6
12		20	10·5	20	10·8	21	10·6	34	16·7
13		33	1·6	14	7·5	4	2·0	9	4·4
15	Haemoptysis	14	7·4	12	6·5	19	9·6	25	12·3
16	Wheeze	67*	35·3	87*	47·0	107	54·0	120	59·1
17		57†	30·0	79†	42·7	81	40·9	75	36·9
18		10	5·3	8	4·3	26	13·1	45	22·2
19	Tightness	47†	24·7	69†	37·3	85	42·9	97	47·8
20		44*	23·2	62*	33·5	67	33·8	71	35·0
21		3	1·6	7	3·8	18	9·1	26	12·8
	Wheeze and tightness	21‡	11·1	49	26·5	60	30·3	78	38·4
22	Chest illness								
	Once	21	11·1	14	7·6	19	9·6	18	8·9
	More than once	7	3·7	5	2·7	35	17·7	30	14·8
	Total	28	14·8	19	10·3	54	27·3	48	23·7
	With increased cough	26	13·7	18	9·7	49	24·7	45	22·2
	With increased sputum	23	12·1	17	9·2	44	22·2	45	22·2
	Breathlessness								
33	,, Grade 1	168	88·4	176	95·1	114	57·6	126	62·1
34	,, 2 and over	22*	11·6	9*	4·9	84	42·4	77	37·9
35	,, 3 and over	—	—	—	—	25	12·6	32	15·8
36	,, 4 and over	—	—	—	—	8	4·0	12	5·9
38	Weather	17	8·9	13	7·0	51	25·8	59	29·1
43	Bouts	18	9·5	18	9·7	54	27·3	49	24·1
44	Bronchitis	11	5·8	11	5·9	53	26·8	49	24·1
	"Chronic bronchitis" (sputum and chest illness)	13	6·8	13	7·0	43	21·7	36	17·7

*Significant 5% level † Significant 2% level ‡ Significant 1% level

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SICKNESS ABSENCE AMONG RAILWAY CLERICAL STAFF

BY

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This paper examines in detail the sickness absence experience within one well-defined railway occupation, identified in a previous paper for further study, namely clerks. The clerks consist of three hierarchical grades. The differences between them are described. The measures of sickness absence are identical with those of the previous communication. A gradient of sickness experience between the three grades is demonstrated. This occurs in inverse relation to the amount of responsibility associated with the posts. The gradient is accounted for by a small number of diagnostic categories. The implication of this is discussed. Comparisons are made with a similar population in London Transport and the results discussed. It is concluded that psychological factors might provide some explanation of the striking differences in sickness experience operating within one sub-class of the Registrar General's classification (IIIc) and within a limited salary scale.

In a previous communication (Gordon, Emerson, and Pugh, 1959b) the patterns of sickness absence among Scottish railwaymen were discussed and certain characteristics of occupations (grades) were examined in relation to the amount of sickness absence experienced. This paper examines further the characteristic of "responsibility" and its relation to the sickness patterns of three hierarchical railway grades. The terms used here are the same as those defined in the previous communication.

Clerical Staff

Among the occupations contained in the railway research population (see previous paper) is that of clerical staff, which is represented by three hierarchical grades, namely chief clerk, senior clerk, and clerk. These distinctions were given to us by the Scottish Regional Establishment and Staff Officer and his colleagues and were described to us as follows:—

A chief clerk exercises a considerable measure of responsibility, is sedentary, and has supervisory duties over other clerks.

A senior clerk does more or less routine work but requiring some measure of initiative, is sedentary, and is normally required to supervise small numbers of clerks.

Clerks require little or no initiative, are sedentary, and do routine work in all departments.

The clerical staff form a homogeneous group in that entry to the higher grades is entirely by promotion from the lower ones. The salaries of railway clerical staff may be noted. They currently range from £540 to £731 per annum depending on the responsibility of the individual post, but not only on supervisory responsibility. Thus a clerk doing specialized and important work may be paid as much as a chief clerk.

Sickness Absence

During the course of the general analysis of the sickness absence data a particular relationship between these grades was discovered. It was found that on all but one of the measures used chief clerks had less sickness absence than senior clerks, who in turn had less than clerks.

In order to make the data on the grades more comparable it was decided to limit the group to clerical staff aged 45 and over, since there are few chief clerks or senior clerks below this age. The data for the clerical staff aged 45+ were age-standardized by the "direct" method (Hill, 1955) and are presented in Table 1. In fact, because of the comparability in age range, age-standardization had very little effect on the actual rates and none at all on the relationship between the grades.

It will be seen that the chief clerks have a smaller number of sickness episodes; these involve a smaller number of people and there are fewer days lost per person during the year. Even when chief clerks

TABLE 1

SICKNESS ABSENCE DATA FOR CLERICAL STAFF

Grade	No. in Group	Episode Rate	Sick Person Rate	Average Duration			Average No. of Episodes per Sick Person
				Per Person (Days Lost in Year)	Per Episode (Days)	Per Sick Person (Days Lost)	
Chief clerk	177	0.52	0.36	7·10	14·67	20·21	1·43
Senior clerk	391	0.58	0.38	10·68	18·28	21·97	1·59
Clerk	692	0.65	0.44	13·14	20·18	29·89	1·49

have a sickness episode, its average duration is shorter. The days lost per sick person are fewer and so are the number of episodes per sick person. All this is so in relation to both the lower grades of clerical staff. The same holds good for senior clerks in relation to clerks, except for a slight departure in the number of episodes per sick person.

Percentage Incidence of Types of Episodes.—In the previous paper it was found that the increase in the amount of sickness for the older age groups is accompanied by a change in the pattern of episode durations and we must now therefore consider whether the larger amount of sickness in clerks involves a similar change of pattern. Table 2 gives the percentage incidence of types of episodes for the three grades.

TABLE 2

PERCENTAGE INCIDENCE OF TYPES OF EPISODE IN CLERICAL STAFF

Length of Episode (days)	Chief Clerks (%)	Senior Clerks (%)	Clerks (%)
Uncertified (1 to 2)	37	30	32
Casual (3 to 6)	20	15	16
Short (7 to 24)	25	34	30
Medium (25 to 72)	12	16	15
Long (73+)	5	5	7
N	87	232	444

N = 100%

The pattern appears to be very much the same for senior clerks and clerks. Compared with both of these there is a tendency for chief clerks to have a somewhat higher percentage of uncertified and casual episodes (57% as compared with 45 and 48) and a correspondingly lower percentage of the remaining types. Thus the differences between chief clerks and the others appear to be due to a lower incidence of episodes of more than one week's duration. This is confirmed by a consideration of the episode rate for different durations in Table 3.

TABLE 3

EPISODE RATES FOR CLERICAL STAFF

Episodes	Chief Clerks	Senior Clerks	Clerks
Uncertified	0·19	0·18	0·20
Casual	0·10	0·09	0·10
Short	0·12	0·20	0·19
Medium	0·06	0·09	0·10
Long	0·02	0·03	0·04

In general it will be seen from Table 3 that clerks have a higher episode rate for all durations (except short) but particularly so for long episodes.

Age Trends in Sickness Absence.—It is also interesting, when comparing the three clerical grades, to consider the age trends in each. Table 4 and Fig. 1 give the average duration per person by age for the clerical staff. The differences between the grades are shown most strikingly on this measure. At each age, rates correspond in ascending magnitude to the hierarchical order.

Clerks show the normal rise with age; the tendency to level off in the oldest age group may be due to the separation of sick workers from the labour force. (Considering the average duration per person for the whole railway research population given in the previous communication, it will be seen that the shape of the curve for age groups 45 to 64 is very similar to that for clerks.) Chief clerks appear to be less prone to sickness absence in that their curve lies entirely below that of the other grades, but there is a very steep rise in the earlier age groups and a sharp decline in the later ones. The rise may be due to the fact that at these ages, fairly soon after they have been promoted, the chief clerks find their adaptation to the job hardest, and thus produce a higher sickness rate. The fall at the older ages may be due to a proportionately greater withdrawal

TABLE 4

AVERAGE NUMBER OF DAYS PER PERSON LOST IN YEAR

Grade	Age Groups (Years)								Total	
	45 to 49		50 to 54		55 to 59		60 to 64			
	No.	Rate	No.	Rate	No.	Rate	No.	Rate	No.	Rate
Chief clerk	30	2·73	46	7·70	69	9·80	32	4·00	177	7·00
Senior clerk	53	7·08	138	9·03	150	13·71	50	12·94	391	11·06
Clerk	144	11·11	287	11·49	204	15·22	57	15·74	692	12·87

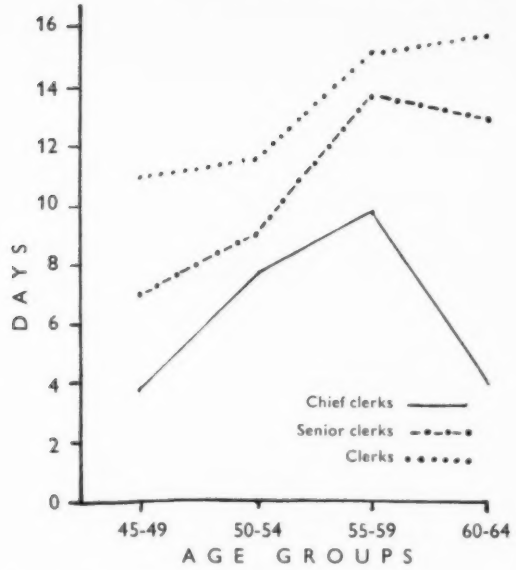

FIG. 1.—Average duration per person (days lost in the year).

from work due to sickness or death than in the other grades. The same considerations may apply but with less force to the intermediate grade of senior clerk. The numbers are small, and some of the results, *e.g.*, the low rate of chief clerks at ages 45-49, might be due, partially at least, to chance.

It is obvious that in addition to age, the length of time in present grade is relevant to this discussion, but to add this as another variable would so attenuate the numbers in the sub-groups as to make the rates very unreliable.

Diagnosis.—For each sickness episode we have available a diagnosis obtained from the doctor's certificate which a man must present when his absence is of three days or longer. When an absence is of only one or two days' duration we have the man's own "diagnosis" which is accepted as sufficient by the railway authorities. Within the limitations inherent in such data an analysis of the diagnoses was carried out.

All causes of sickness absence were broken down into broad diagnostic categories. The grouping of London Transport Executive (1956) was used in order to make direct comparison with their results, and because it appeared suitable for the limited examination which our information would permit.

The diagnostic categories in which a gradient exists were demonstrated by the use of the ratios clerk: senior clerk and senior clerk: chief clerk, using the measure of average duration per person. The gradient was shown to exist in six categories,

TABLE 5

AVERAGE DURATION OF SICKNESS ABSENCE PER PERSON IN DIFFERENT DIAGNOSTIC GROUPS

Grades	Diagnostic Groups		Total (days)
	*Special (days)	Other (days)	
Chief clerk	2·25	4·75	7·00
Senior clerk	5·42	5·63	11·05
Clerk	7·48	5·39	12·87

*(*a*) Functional nervous disorders, (*b*) bronchitis, (*c*) diseases of circulatory system, (*d*) diseases of stomach and duodenum, (*e*) accidents, (*f*) diseases of bones and organs of movement.

namely: (*a*) functional nervous disorders, (*b*) bronchitis, (*c*) diseases of the circulatory system, (*d*) diseases of the stomach and duodenum, (*e*) accidents, and (*f*) diseases of bones and organs of movement. It is shown in Table 5 that if these six categories are ignored, no gradient exists, and therefore these categories are responsible for the total gradient. We found no evidence of a gradient going in the opposite direction.

Definitions of Diagnoses.—It should be noted that "functional nervous disorders" include both psychotic and neurotic mental illness, and that in the category "bronchitis" no distinction is made between the acute and chronic forms.

"Diseases of the circulatory system" includes all heart conditions except congenital heart disease, all hypertensive heart disease, diseases of arteries and veins, as well as ill-defined symptoms referable to this system.

"Diseases of the stomach and duodenum" includes peptic ulcer and other diseases of the stomach and duodenum, but not carcinoma.

"Diseases of bones and organs of movement" includes arthritis and rheumatism, osteomyelitis and other diseases of bones and joints, but not rheumatic fever.

The category "accidents" presents a different problem as we did not make the distinction between accidents on and off duty that was made by London Transport. For purposes of comparison we have grouped their two categories together.

Comparisons with London Transport Clerical and Technical Staff (Men)

Comparisons with an apparently similar population in London Transport are given in Tables 6 and 7. London Transport regards all episodes of six months or more as being of six months only, and ignores all episodes of three days or less. For comparison our figures have been corrected on this basis.

We have also made corrections in the categories "common cold" and "influenza" to compensate for some obvious anomalies in our figures. In the first

TABLE 6

COMPARISON OF SICKNESS RATES AND DURATION FOR CLERICAL STAFF OF THE RAILWAY RESEARCH POPULATION AND LONDON TRANSPORT

Age Group (years)	Episode Rate		Average Duration			
			Per Episode		Per Person	
	Railway Research Population (days)	London Transport (days)	Railway Research Population (days)	London Transport (days)	Railway Research Population (days)	London Transport (days)
45 to 49	0·34	0·39	24·65	20·19	8·36	7·79
50 to 54	0·37	0·41	25·17	22·78	9·23	9·36
55 to 59	0·42	0·44	30·51	29·21	12·84	12·71
60 to 64	0·37	0·48	26·81	30·81	10·03	14·76

TABLE 7

AVERAGE DURATION OF SICKNESS PER PERSON FOR CLERICAL STAFF OF THE RAILWAY RESEARCH POPULATION AND LONDON TRANSPORT

Age Groups (years)	Special Diagnostic Groups		Other Groups		Total	
	Railway Research Population (days)	London Transport (days)	Railway Research Population (days)	London Transport (days)	Railway Research Population (days)	London Transport (days)
45 to 49	2·10	3·55	6·26	4·24	8·36	7·79
50 to 54	5·26	3·86	3·96	5·50	9·22	9·36
55 to 59	8·32	6·92	4·52	5·79	12·84	12·71
60 to 64	6·47	8·01	3·56	6·75	10·03	14·76

all episodes of 28 days or over are regarded as of 28 days only, and in the second, all episodes of 42 days or over are regarded as of 42 days only.

From Table 6 it can be seen that the episode rate is lower, and the average duration per episode is higher in the railway research population than in London Transport. These figures bear out the different patterns of sickness absence already noted in the previous paper, though the clerks resemble each other more closely than do the groups as a whole. On the measure of average duration per person (Table 7), this resemblance is again marked.

Comparison of the special and other diagnostic groups by age with London Transport is given in Table 7. It can be seen that the average duration per person rises with age in the special groups both in London Transport and in the railway research population, but there is no rise in the other groups in the railway research population, and only a slight rise in London Transport.

Sickness Absence Effects on Promotion

One of the major questions immediately posed by the above results is the following: Is it the absence of malfunction with attendant lack of sickness which leads to promotion, or does the failure to achieve promotion induce malfunction? It is clear that a consideration of the data derived from recording job changes in the railway research population would be relevant. Unfortunately, the available material relating to changing of job is only for the period of a year and covers a comparatively small number of changes with consequent relative unreliability of the measures. With this caution in mind it is presented here as a first estimate.

Of the 92 clerks who were promoted during the year, 28 had some form of sickness absence. This gives a sick person rate of 0.30 compared with 0.44 for all clerks. Similarly seven of the 21 senior clerks promoted had a sickness absence, giving a sick person rate of 0.33 compared with 0.38 for all senior clerks. Thus, as far as it goes, the available information supports the hypothesis that there is some medical factor involved in selection, although its precise degree has yet to be determined.

Conclusions

In this paper we have described the sickness absence experience of a specific occupational group (railway clerical staff) and have demonstrated that a gradient of sickness exists among its hierarchical grades. This gradient is inversely related to the amount of supervisory responsibility carried by the posts. Supervisory staffs are healthier than their subordinates of the same age as shown by such measures as the percentage of men who have a sickness absence during the year, and the number of days lost per person through sickness. Also the pattern of episode durations is different; chief clerks have a significantly higher percentage of shorter sickness absences of less than one week, and a correspondingly lower percentage of longer episodes.

We have also shown that the gradient is provided

by a limited number of diagnostic categories which include functional nervous disorders, and diseases of the stomach and duodenum. These might suggest a psychosomatic element, although it is difficult to see how the remaining categories showing the gradient can be reconciled with this. It is clear that there are other factors at work.

From the point of view of social medicine the gradient demonstrated here is of particular interest since we are not measuring social class differences. The gradient operates within a very small salary range, among persons who all belong to class IIIc in the Registrar General's classification. We are tapping intra-class differences where such psychological factors as morale, attitude to work, and "absence threshold" become central. A closer examination of industrial groups which present a homogeneity otherwise difficult to obtain, might throw some light on disputed questions in the aetiology of diseases and especially on the common origin of seemingly separate diseases. We hope that other such studies as this will be forthcoming.

This work was started with encouragement from the Human Relations Committee of the Department of Scientific and Industrial Research and the Medical Research Council. We are grateful to the Medical Research Council for a grant in aid.

We are happy to acknowledge the very great help of the Establishment and Staff Office of the Scottish Region of British Railways through Mr. C. H. Brazier, Mr. D. F. Gowen, Mr. J. Weston, and Mr. D. Murray. We are grateful to Dr. W. A. R. Mailer and Dr. J. D. Galletly of the Medical Department. Thanks are also due to Mr. M. G. Bennet, Operational Research Division of the British Transport Commision.

The work has had the friendly interest of the trade unions concerned.

We have had much assistance from Gene McKinnon, Patricia Taylor, and Jane Walsh (research auxiliaries), John Nimmo (Hollerith technician), and Gertrude Cleary (clerk).

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PNEUMOCONIOSIS IN CARBON ELECTRODE MAKERS

BY

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In the absence of adequate preventive measures the manufacture of carbon electrodes is attended by a considerable dust hazard. The present paper is based on a study of the clinical, radiological, and pathological changes resulting from inhalation of this dust, which is derived from crushed coke and anthracite.

An account is given of the findings in a clinical survey of 15 men who had been employed for at least 10 years in manufacturing carbon electrodes. Four of these men were suffering from complicated and five from simple pneumoconiosis.

In addition, the findings in three necropsied cases (two complicated and one simple) are recorded in detail. Bacteriological examination of the lungs and analysis of the lung dust was carried out in the two cases of complicated pneumoconiosis.

It is shown that carbon electrode makers may develop simple pneumoconiosis with focal emphysema and that this may be complicated by the development of massive fibrotic lesions. Both the simple and the complicated pneumoconiosis are indistinguishable from the corresponding conditions in other coalworkers.

Quartz was almost entirely absent from the lung dust of the two necropsied cases with massive fibrosis and in one of these cases virulent tubercle bacilli were shown. The significance of these findings is discussed in relation to the aetiology of progressive massive fibrosis. While it is evident that they are incompatible with the "silica" theory they provide some limited support for the "tuberculosis" theory.

The manufacture of carbon electrodes involves the production of much dust which must inevitably be inhaled unless efficient dust control is achieved; the dust consists mainly of coal and coke particles. It is the purpose of this paper to present clinical, radiological, and pathological evidence that prolonged exposure to such dust causes the development of pneumoconiosis indistinguishable from that of coalworkers in both its simple and its complicated varieties. Two necropsied cases with complicated pneumoconiosis afforded the opportunity to compare the characteristics of the massive fibrotic lesions and their contained dust with those of the corresponding lesions in cases of complicated pneumoconiosis of other coalworkers. The findings are discussed in relation to the possible aetiology of this condition.

The Process

In the process of carbon electrode manufacture at the factory with which we are concerned the raw material is principally a mixture of coke and anthracite. After pulverization these are mixed with a binding agent, usually pitch, and then pressed into the desired shapes. The processes involve crushing, milling, and sieving the coke, anthracite, and scrap electrode material, mixing with hot pitch as the binding agent, shaping in presses, baking the shapes in furnaces, and lastly, fettling their surfaces with hand or pneumatic tools. At almost all stages of the process very large quantities of dust are produced, with which the measures of dust suppression in use until 1945 were quite unable to cope efficiently. At the end of the war, long delayed plans for rebuilding and improving the plant were put into effect and by 1948 rather more than half of the works had been modernized by installing new plant to enclose the dusty processes, to transport materials mechanically, and to provide efficient local exhaust ventilation where required. Since then further improvements have been carried out to plant and premises and, in addition, an excellent scheme of medical supervision of the workers has been instituted, which includes initial and periodical medical examinations. Periodical checks on environmental conditions by dust counting are also carried out.

Clinical Survey

In 1948, the possibility of a pneumoconiosis risk in the process was suggested to one of us (A.T.D.) by Dr. J. M. M. Jamieson (now in Kenya). Working conditions were investigated, and clinical and radiological examinations were carried out on 15 workers. These 15 men comprised all those on one shift who had been employed for 10 years or more on the process. Nine cases of pneumoconiosis were found; five of these cases were in the category of simple pneumoconiosis and the remaining four cases were of the complicated variety. The detailed findings are given in Table 1. The radiological classification adopted conforms to that evolved by the M.R.C. Pneumoconiosis Research Unit in Cardiff (Fletcher, Mann, Davies, Cochrane, Gilson, and Hugh-Jones, 1949).

TABLE 1

PARTICULARS OF 15 CARBON ELECTRODE WORKERS INCLUDED IN THE CLINICAL SURVEY

Case	Age (years)	Exposure (years)	Radiograph of Chest
1 (S.H.)	52	28	Normal
2 (G.B.)	34	16	Normal
3 (W.R.)	35	10½	Normal
4 (N.L.)	60	25	Increased vascular markings
5 (J.M.)	57	28	Increased vascular markings
6 (D.M.)	59	37	Emphysema
7 (A.M.)	60	34½	Simple pneumoconiosis, Cat. 2
8 (P.D.)	46	16	Simple pneumoconiosis, Cat. 2
9 (D.W.)	34	13	Simple pneumoconiosis, Cat. 2
10 (S.M.)	54	32	Simple pneumoconiosis, Cat. 2
11 (J.D.)	64	28½	Simple pneumoconiosis, Cat. 2
12 (H.C.)	62	39	Complicated pneumoconiosis, 2A 1/0
13 (R.K.)	64	18	Complicated pneumoconiosis, 3A 2/1
14 (J.M.)	65	30	Complicated pneumoconiosis with emphysema, 3C 4/1
15 (G.G.)	61	19	Complicated pneumoconiosis, 3B 3/2

Age and Duration of Exposure.—The ages of the 15 workers ranged from 34 to 65 years (mean 53·8) and experience in the process from 10½ to 39 years (mean 25·6). The mean duration of employment of the men whose chest radiographs were classed as normal was 18·2 years; of those with simple pneumoconiosis, 24·8 years; and of those with complicated pneumoconiosis, 26·5 years. As the factory is situated in a non-industrial area, previous occupations were mainly agricultural, horticultural, and soldiering. Only two men had been engaged in previous occupations with a dust hazard, one as a slate dresser for seven years (Case 6, found not to have pneumoconiosis) and the other as a foundry labourer for one year (Case 7, with simple pneumoconiosis). The pneumoconiotic lesions found can therefore be attributed entirely to the dust exposure in electrode making.

Clinical.—Two of the four men with complicated pneumoconiosis gave a history of previous respiratory illness, recent severe bronchitis in one case (Case 15) and pneumonia and pleurisy 23 years previously in another (Case 12). A third man in this group (Case 13) said that he had been suspected of having pleurisy five years before. Two of these men (Cases 12 and 13) had slight or occasional symptoms consisting of cough, dyspnoea, and sputum; the other two had more severe symptoms, and Case 14 had been given a light job because of dyspnoea. This man showed hyperresonance on percussion, with a diminished area of cardiac dullness and pleural friction at the right base. In Case 12, sonorous and sibilant rhonchi were heard, but in the other two cases there were only basal crepitations. Chest expansion was notably reduced in all four men, the mean being 1·4 in. (3·5 cm.).

None of the five men with simple pneumoconiosis had a history of previous respiratory illness and two of them (Cases 7 and 9) were quite free of chest symptoms. One man (Case 11) was considerably disabled by dyspnoea, but this was probably mainly due to auricular fibrillation; the other two men had only mild symptoms. No abnormalities as regards percussion and auscultation were encountered in three cases (Cases 7, 9, and 11) and in the other two there was little apart from basal crepitations. The mean chest expanison in this group was 1·6 in. (4·5 cm.).

In the group of six men without pneumoconiosis, none gave a history of previous respiratory illness; three had slight occasional cough, two had occasional sputum, and one was doubtful about the presence of slight dyspnoea. Two of this group (Cases 1 and 5) had basal crepitations and, in addition, one of them had signs of emphysema. The mean chest expansion was 2·2 in. (5·6 cm.).

Radiological.—The appearances of the radiographs were within normal limits in three patients (Cases 1, 2, and 3), showed increased vascular markings in two (Cases 4 and 5), and suggested the presence of emphysema in one (Case 6). The five cases showing the changes of simple pneumoconiosis were Cases 7, 8, 9, 10, and 11, and the four showing complicated pneumoconiosis were Cases 12, 13, 14, and 15.

Details of Three Necropsied Cases

One of the men (Case 15) examined in the course of the clinical survey and found to be suffering from complicated pneumoconiosis has since died. A necropsy was performed on this man and on two other carbon electrode makers from the same factory who were not included in the survey; one of these (Case 16) was a case of complicated pneumoconiosis and the other (Case 17) a case of simple pneumoconiosis. A full account of the clinical and pathological findings in all three cases is given below

and the results of an analysis of the lung dust in the two with massive fibrosis are also recorded.*

Case 15.—This man, aged 70 when he died in August, 1958, had been engaged in the manufacture of carbon electrodes for 19 years. From 1946 he was incapacitated by his chest condition for some 20 months, resuming lighter work in 1948. In July, 1952, he was considered to be totally disabled by pneumoconiosis, his chief complaint at this time being shortness of breath on exertion which was apparent during examination. He also suffered from an intermittent cough accompanied by sputum. Nutrition was average, chest expansion was poor. On auscultation the breath sounds were high pitched, with prolongation of the expiratory murmur. Air entry was rather poor and a few rhonchi were heard over the lower zones of the chest posteriorly. Radiological examination of the chest showed the appearances of complicated pneumoconiosis, category 3B 3/2 (Fig. 1).

Post-mortem Examination.—The subject was a strongly built, well-nourished, elderly man with considerable pitting oedema of the legs and feet. Dissection showed that the pleural sacs were partially obliterated posteriorly by fibrous adhesions. The trachea and major bronchi appeared normal. The lungs were abnormally heavy and bulky and failed to collapse when the thorax was opened. Large emphysematous bullae were present at the apices and along the anterior margins of the lungs. Posteriorly the lungs showed coarse cicatrization in relation to underlying fibrous masses. Although heavily dust-impregnated the hilar and tracheo-bronchial lymph nodes were only slightly enlarged. The right lung (780 g.) was sliced before fixation, disclosing numerous small, soft, dust-impregnated foci, each attended by a severe degree of focal emphysema. In addition, larger palpable foci up to 1·0 cm. in diameter were sparsely distributed throughout all the lobes. A black fibrotic mass about 6·0 cm. in diameter was present in the parahilar zone of the upper lobe and nearby, in the superior segment of the lower lobe, there was a similar mass measuring 5·0 × 4·0 cm. on hemisection. Both these lesions were fairly well circumscribed and had a slightly compressible rubbery consistence; neither showed central necrosis. The left lung (740 g.) was fixed in the position of inflation by running formol saline into the air passages. Slicing of the lung showed appearances very similar to those described in the right lung: numerous soft dust foci with severe focal emphysema, scattered small palpable foci, and two large fibrotic masses were noted. One of the massive lesions was situated at the apex of the upper lobe and the other at the apex of the lower lobe; both were solid, rubbery, and discrete, measuring about 5·0 cm. in diameter. These lesions are illustrated in the accompanying reproduction of a thin sagittal section of the whole left lung (Fig. 2). In both lungs the pulmonary

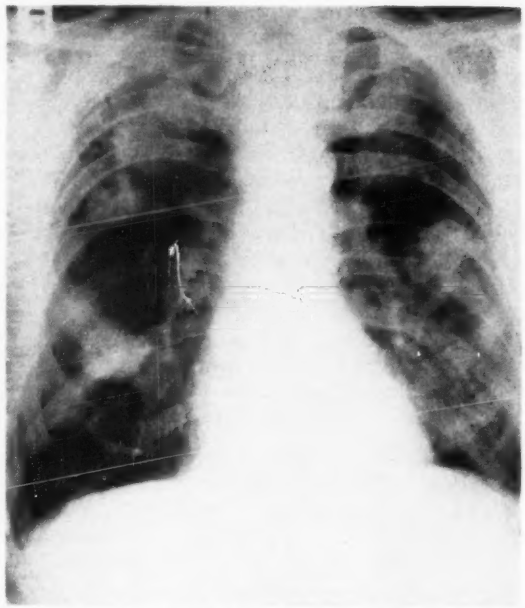

FIG. 1.—Case 15. Carbon electrode maker for 19 years. Chest radiograph showing complicated pneumoconiosis, category 3B 3/2.

arteries were extremely atheromatous and ante-mortem thrombus was present in many of the larger divisions, extending more peripherally in the left lower lobe where there was a large red infarct in the lateral basal segment. There was no gross evidence of tuberculosis or of pneumonic consolidation in either lung.

The heart was markedly enlarged due to hypertrophy of both ventricles, particularly the right. The coronary arteries were sclerotic and showed widespread atheromatous degeneration resulting in almost complete occlusion of the anterior descending branch of the left coronary artery. There was myocardial fibrosis but no evidence of infarction. Apart from changes due to chronic venous congestion in the liver and slight surface granularity of the kidneys, other organs showed no notable abnormality.

Histology.—Microscopical examination of the massive dust-impregnated lesions in both lungs showed that they had a fairly uniform structure. This consisted of a connective tissue meshwork with its interstices filled by small aggregates of black dust particles. Because of the density of these aggregates it was impossible to determine whether or not the dust lay free or was contained within macrophages. The arrangement and uniform size of the aggregates suggested that the dust was mainly intracellular (Fig. 3). The bands of connective tissue constituting the meshwork were generally of a loose nature but in places they were densely collagenous and thicker. In addition, these massive lesions were intersected by a few prominent collagenous septa bearing large blood vessels. Some of the pulmonary artery branches in these septa were collapsed and occluded. The appearance of the smaller fibrotic nodules in the lungs was essentially similar to that of the massive lesions, the difference being

*Case 13, another of the men in the clinical survey with complicated pneumoconiosis, has also died. We are indebted to Dr. T. Skeoch of Middlesbrough, who carried out a post-mortem examination, for an account of the findings and for the opportunity to examine histological sections of the lungs. The gross and microscopical appearances of the lungs were indistinguishable from coalworkers' pneumoconiosis with massive fibrotic lesions. Unfortunately the lungs were not retained for dust analysis.

FIG. 2

FIG. 2.—Case 15. Thin parasagittal section of whole left lung showing massive fibrotic lesion in posterior part of the lower lobe. Elsewhere there are numerous small dust foci with severe focal emphysema. Emphysematous bullae are present antero-superiorly.

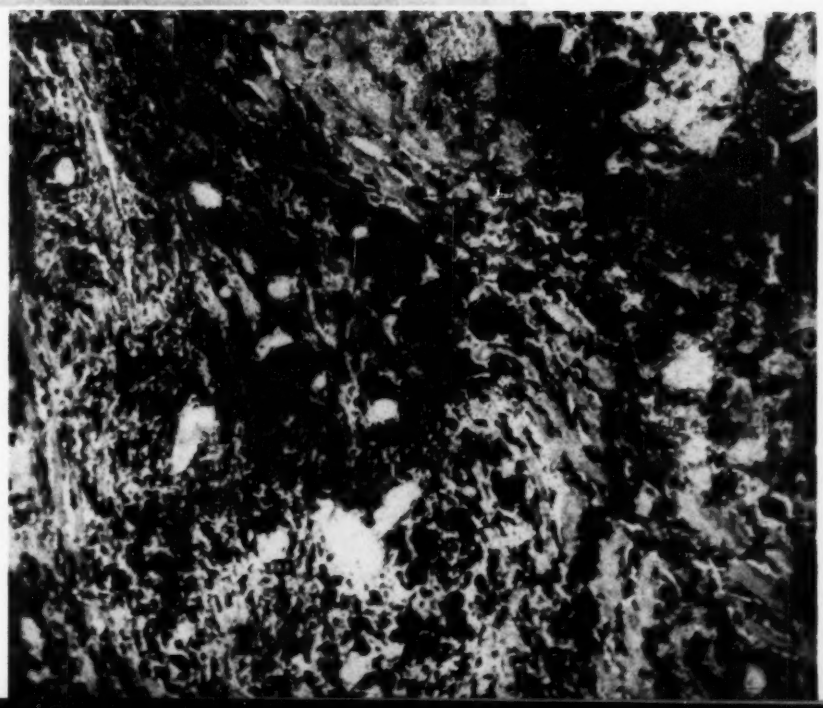

FIG. 3

FIG. 3.—Case 15. This illustrates the structure of the massive fibrotic lesions, consisting of a collagenous meshwork with the interstices filled by aggregates of dust particles. × 180 (Masson).

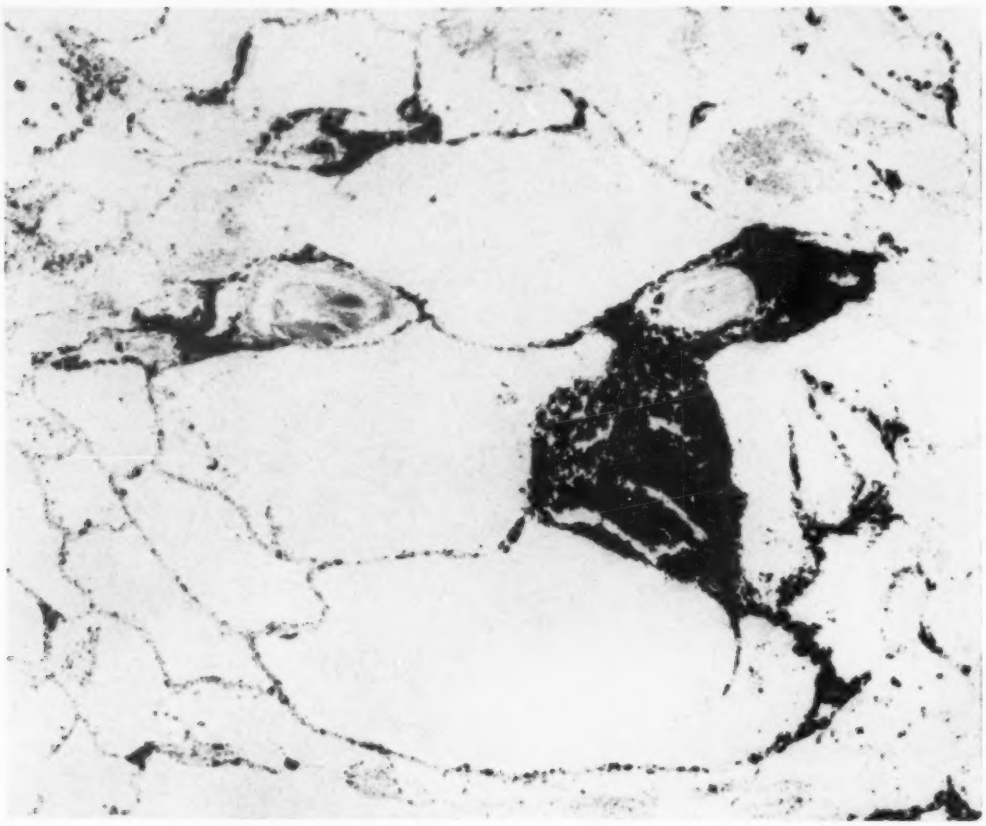

FIG. 4.—Case 15. Characteristic small dust deposit with well developed focal emphysema. ×40 (haematoxylin and eosin).

merely one of size. In the spongy parts of the lungs there were numerous, small, stellate accumulations of dust particles, often investing small branches of the pulmonary arteries and sending fine extensions into the interalveolar septa. As in the case of the massive lesions, it appeared that the dust was mostly contained within macrophages and these were enmeshed in a fine connective tissue network. It was confirmed that there was a severe degree of focal emphysema in relation to these small dust aggregates (Fig. 4). The hilar lymph nodes were also heavily impregnated with dust and showed areas of fibrosis. Examination of the various sections in polarized light showed very few doubly refractile dust particles. Evidence of chronic bronchitis was noted and some of the bronchial arteries showed considerable medial hypertrophy.

Bacteriology.—Material from one of the massive lesions in the right lung was examined for the presence of tubercle bacilli. These could not be demonstrated in direct smears nor by guinea-pig inoculation.

Case 16.—This patient died in November, 1956, at the age of 73 years. He had been employed in the manufacture of carbon electrodes for 18 years between 1930 and 1948. Previously he had been a blacksmith for 11 years, and had then served in the Regular Army for 12 years. He had enjoyed good health until he developed pneumonia in 1948 when he finally ceased work; before that date he had had a cough for some time. In 1952 he complained of severe cough at night with expectoration which was sometimes black. Dyspnoea severely limited his walking exercise and he suffered from chest pain, lassitude, and giddiness. Examination showed him to be of spare build though he had formerly been stout. The chest was flattened and expansion was poor. Some impairment of the percussion note was present, especially in the upper zones, and breath sounds were weak with prolongation of the expiratory murmur. Scattered rhonchi were heard throughout both lungs and crepitations at the bases. The chest radiograph showed fine discrete shadows throughout both lung fields with increased lung markings extending slightly into the peripheral zone; large, dense, woolly opacities were present on both sides in the perihilar areas; the classification was 2B 3/2 (Fig. 5). In January, 1953, he was certified as being totally disabled on account of pneumoconiosis.

Post-mortem Examination.—The body was extremely wasted and emaciated and there was severe pitting

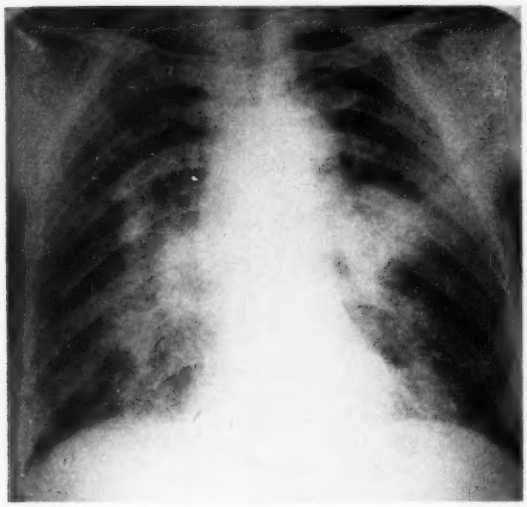

FIG. 5.—Case 16. Carbon electrode maker for 18 years. Chest radiograph showing fine discrete shadows and perihilar massive fibrosis, category 2B 3/2.

oedema of the feet and ankles. The left pleural sac was almost completely obliterated by dense fibrous adhesions, but in the right pleural sac there were only some apical fibrous adhesions. The trachea and bronchi contained a large quantity of black, turbid, watery fluid. The right lung was voluminous and heavy (1,370 g.) and was fixed in the inflated position by perfusing the air passages with formal saline. Slicing of the lung then disclosed a large, irregular, black, fibrous mass, approximately 8·0 cm. in diameter, occupying the central, parahilar zone of the upper lobe but also involving the adjacent parts of the middle and lower lobes. In the centre of this massive fibrotic lesion there was an irregular cavity measuring up to 4·0 cm. in diameter filled with black, turbid fluid. The remainder of the right lung was studded with numerous small, soft, dust-impregnated foci attended by a severe degree of focal emphysema. A few fibrous nodules, up to 2·0 cm. in diameter, were also distributed sparsely throughout the lung. Some bronchiectasis was present in relation to the fibrotic lesions. These various features are demonstrated in the accompanying photograph of a sagittal thin section of the right lung (Fig. 6). The left lung was also large and heavy (970 g.) and was cut unfixed so that material might be obtained for bacteriological examination. In the anterior segment of the upper lobe there was a large irregular cavity, containing black, turbid fluid, and measuring 7·0 × 5·0 cm. on hemisection. The wall of this cavity was composed of dense, black, fibrous tissue, and was up to 2·0 cm. in thickness. A similar thick-walled cavity was present in the superior segment of the lower lobe. Other parts of the left lung were studded with numerous soft and some small palpable dust foci, the soft foci being associated with severe focal emphysema. There was general ectasia of the larger bronchi in both lobes but this was most prominent in the upper lobe. The hilar and mediastinal lymph nodes were moderately enlarged, black, and fibrotic. The heart (200 g.) showed the appearances of brown atrophy and the coronary arteries were moderately atheromatous. Other organs showed no significant abnormality.

Histology.—Microscopical examination of the massive fibrotic lesions in both lungs showed that their structure was basically similar to that of the corresponding lesions in Case 15. They consisted, for the most part, of a close meshwork of collagenous connective tissue in which the interstices were filled by innumerable small (intracellular?) aggregates of black particulate material giving a densely impregnated appearance. In these massive lesions occasional small foci of coagulative necrosis were present (Fig. 7), separated from the investing dust-impregnated collagenous tissue by narrow zones of granulation tissue infiltrated by macrophages. It was possible to discern in the central necrotic areas the outline of pre-existing emphysematous spaces filled with necrotic cells and it was notable that these were quite free of dust particles. Although the usual histological stigmata of tuberculosis were absent, the necrotic material had an appearance reminiscent of caseation, and the presence of moderately numerous acid- and alcohol-fast bacilli confirmed the tuberculous nature of the lesions. The walls of the bronchi in and around the massive lesions were generally fibrotic and the mucosal lining was often replaced by granulation tissue densely infiltrated by plasma cells and macrophages. Many bronchial arteries showed severe degrees of obliterative endarteritis (Fig. 8).

In those parts of the lungs which were not involved in the massive fibrotic lesions there were numerous small focal dust deposits, usually with a crenated or scalloped outline and generally similar to those seen in Case 15. These smaller foci often appeared to be perivascular or peribronchiolar and focal emphysema was a prominent feature in relation to most of them. Throughout both lungs there was, in addition to the above findings, widespread acute bronchopneumonic consolidation. Examination of the dust-impregnated areas by means of polarized light showed that there were very few doubly refractile particles. In the hilar lymph nodes there was extensive dust impregnation and fibrosis similar to that seen in the lungs, but no evidence of caseous necrosis.

Bacteriology.—Tubercle bacilli were cultured from the wall of one of the cavities in the left lung and were shown by guinea-pig inoculation to be virulent.

Case 17.—This man, aged 61, had been employed as a carbon electrode process worker from 1922 until 1939, having previously served in the Army and engaged in agricultural work. He had a further period of service in the Armed Forces from 1939 until 1944, being discharged on account of "epilepsy". He then undertook light labouring duties in an engineering workshop until he finally gave up work because of illness in 1954. A cough which he had had for some time became severe and was accompanied by sputum, occasionally with haemoptysis. Dyspnoea became noticeable and he complained of pain across the chest, giddiness, headache, and lassitude. Clinical examination in January, 1953, showed him to be of fair nutrition and without cyanosis, finger clubbing, or oedema. There were no abnormal signs in the chest,

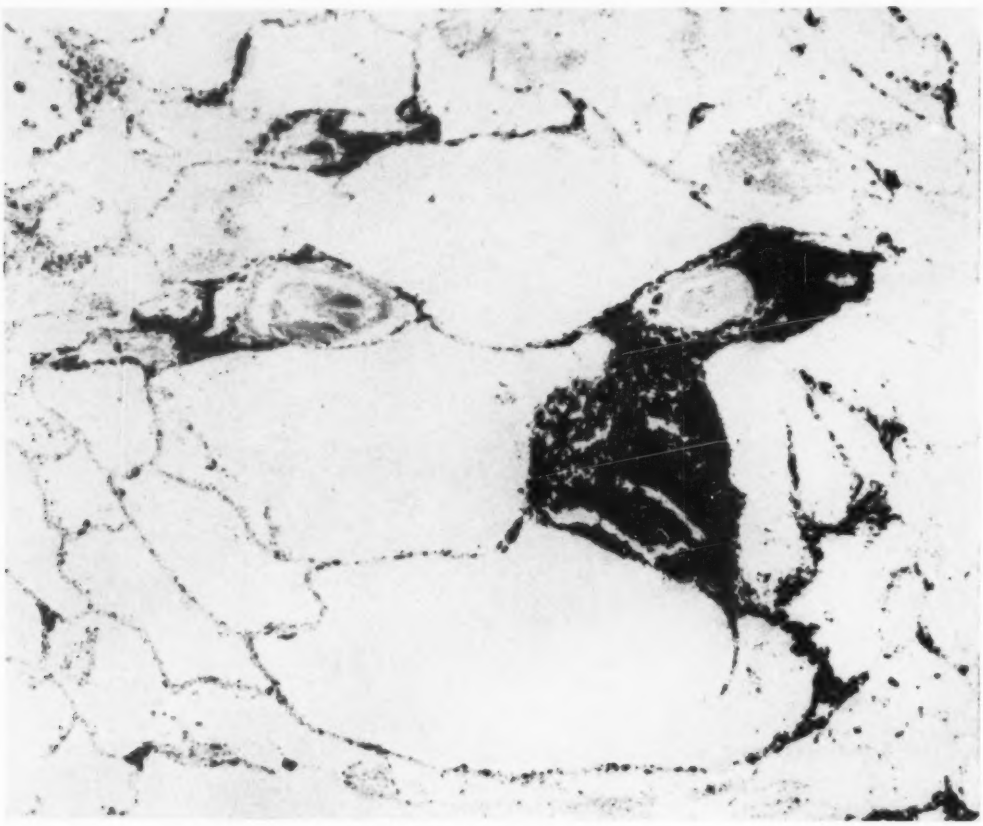

FIG. 4.—Case 15. Characteristic small dust deposit with well developed focal emphysema. × 40 (haematoxylin and eosin).

merely one of size. In the spongy parts of the lungs there were numerous, small, stellate accumulations of dust particles, often investing small branches of the pulmonary arteries and sending fine extensions into the interalveolar septa. As in the case of the massive lesions, it appeared that the dust was mostly contained within macrophages and these were enmeshed in a fine connective tissue network. It was confirmed that there was a severe degree of focal emphysema in relation to these small dust aggregates (Fig. 4). The hilar lymph nodes were also heavily impregnated with dust and showed areas of fibrosis. Examination of the various sections in polarized light showed very few doubly refractile dust particles. Evidence of chronic bronchitis was noted and some of the bronchial arteries showed considerable medial hypertrophy.

Bacteriology.—Material from one of the massive lesions in the right lung was examined for the presence of tubercle bacilli. These could not be demonstrated in direct smears nor by guinea-pig inoculation.

Case 16.—This patient died in November, 1956, at the age of 73 years. He had been employed in the manufacture of carbon electrodes for 18 years between 1930 and 1948. Previously he had been a blacksmith for 11 years, and had then served in the Regular Army for 12 years. He had enjoyed good health until he developed pneumonia in 1948 when he finally ceased work; before that date he had had a cough for some time. In 1952 he complained of severe cough at night with expectoration which was sometimes black. Dyspnoea severely limited his walking exercise and he suffered from chest pain, lassitude, and giddiness. Examination showed him to be of spare build though he had formerly been stout. The chest was flattened and expansion was poor. Some impairment of the percussion note was present, especially in the upper zones, and breath sounds were weak with prolongation of the expiratory murmur. Scattered rhonchi were heard throughout both lungs and crepitations at the bases. The chest radiograph showed fine discrete shadows throughout both lung fields with increased lung markings extending slightly into the peripheral zone; large, dense, woolly opacities were present on both sides in the perihilar areas; the classification was 2B 3/2 (Fig. 5). In January, 1953, he was certified as being totally disabled on account of pneumoconiosis.

Post-mortem Examination.—The body was extremely wasted and emaciated and there was severe pitting

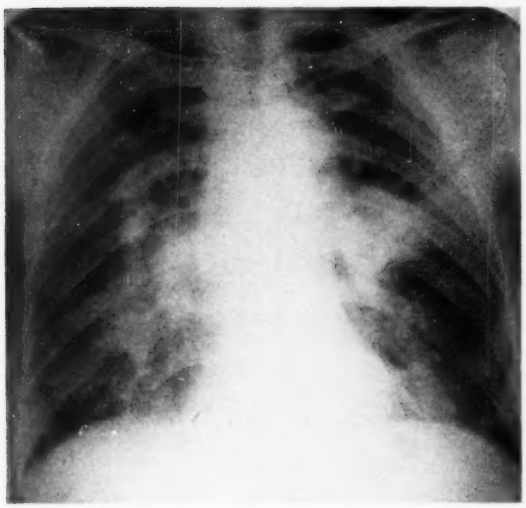

FIG. 5.—Case 16. Carbon electrode maker for 18 years. Chest radiograph showing fine discrete shadows and perihilar massive fibrosis, category 2B 3/2.

oedema of the feet and ankles. The left pleural sac was almost completely obliterated by dense fibrous adhesions, but in the right pleural sac there were only some apical fibrous adhesions. The trachea and bronchi contained a large quantity of black, turbid, watery fluid. The right lung was voluminous and heavy (1,370 g.) and was fixed in the inflated position by perfusing the air passages with formal saline. Slicing of the lung then disclosed a large, irregular, black, fibrous mass, approximately 8·0 cm. in diameter, occupying the central, parahilar zone of the upper lobe but also involving the adjacent parts of the middle and lower lobes. In the centre of this massive fibrotic lesion there was an irregular cavity measuring up to 4·0 cm. in diameter filled with black, turbid fluid. The remainder of the right lung was studded with numerous small, soft, dust-impregnated foci attended by a severe degree of focal emphysema. A few fibrous nodules, up to 2·0 cm. in diameter, were also distributed sparsely throughout the lung. Some bronchiectasis was present in relation to the fibrotic lesions. These various features are demonstrated in the accompanying photograph of a sagittal thin section of the right lung (Fig. 6). The left lung was also large and heavy (970 g.) and was cut unfixed so that material might be obtained for bacteriological examination. In the anterior segment of the upper lobe there was a large irregular cavity, containing black, turbid fluid, and measuring 7·0 × 5·0 cm. on hemisection. The wall of this cavity was composed of dense, black, fibrous tissue, and was up to 2·0 cm. in thickness. A similar thick-walled cavity was present in the superior segment of the lower lobe. Other parts of the left lung were studded with numerous soft and some small palpable dust foci, the soft foci being associated with severe focal emphysema. There was general ectasia of the larger bronchi in both lobes but this was most prominent in the upper lobe. The hilar and mediastinal lymph nodes were moderately enlarged, black, and fibrotic. The heart (200 g.) showed the appearances of brown atrophy and the coronary arteries were moderately atheromatous. Other organs showed no significant abnormality.

Histology.—Microscopical examination of the massive fibrotic lesions in both lungs showed that their structure was basically similar to that of the corresponding lesions in Case 15. They consisted, for the most part, of a close meshwork of collagenous connective tissue in which the interstices were filled by innumerable small (intracellular?) aggregates of black particulate material giving a densely impregnated appearance. In these massive lesions occasional small foci of coagulative necrosis were present (Fig. 7), separated from the investing dust-impregnated collagenous tissue by narrow zones of granulation tissue infiltrated by macrophages. It was possible to discern in the central necrotic areas the outline of pre-existing emphysematous spaces filled with necrotic cells and it was notable that these were quite free of dust particles. Although the usual histological stigmata of tuberculosis were absent, the necrotic material had an appearance reminiscent of caseation, and the presence of moderately numerous acid- and alcohol-fast bacilli confirmed the tuberculous nature of the lesions. The walls of the bronchi in and around the massive lesions were generally fibrotic and the mucosal lining was often replaced by granulation tissue densely infiltrated by plasma cells and macrophages. Many bronchial arteries showed severe degrees of obliterative endarteritis (Fig. 8).

In those parts of the lungs which were not involved in the massive fibrotic lesions there were numerous small focal dust deposits, usually with a crenated or scalloped outline and generally similar to those seen in Case 15. These smaller foci often appeared to be perivascular or peribronchiolar and focal emphysema was a prominent feature in relation to most of them. Throughout both lungs there was, in addition to the above findings, widespread acute bronchopneumonic consolidation. Examination of the dust-impregnated areas by means of polarized light showed that there were very few doubly refractile particles. In the hilar lymph nodes there was extensive dust impregnation and fibrosis similar to that seen in the lungs, but no evidence of caseous necrosis.

Bacteriology.—Tubercle bacilli were cultured from the wall of one of the cavities in the left lung and were shown by guinea-pig inoculation to be virulent.

Case 17.—This man, aged 61, had been employed as a carbon electrode process worker from 1922 until 1939, having previously served in the Army and engaged in agricultural work. He had a further period of service in the Armed Forces from 1939 until 1944, being discharged on account of "epilepsy". He then undertook light labouring duties in an engineering workshop until he finally gave up work because of illness in 1954. A cough which he had had for some time became severe and was accompanied by sputum, occasionally with haemoptysis. Dyspnoea became noticeable and he complained of pain across the chest, giddiness, headache, and lassitude. Clinical examination in January, 1953, showed him to be of fair nutrition and without cyanosis, finger clubbing, or oedema. There were no abnormal signs in the chest,

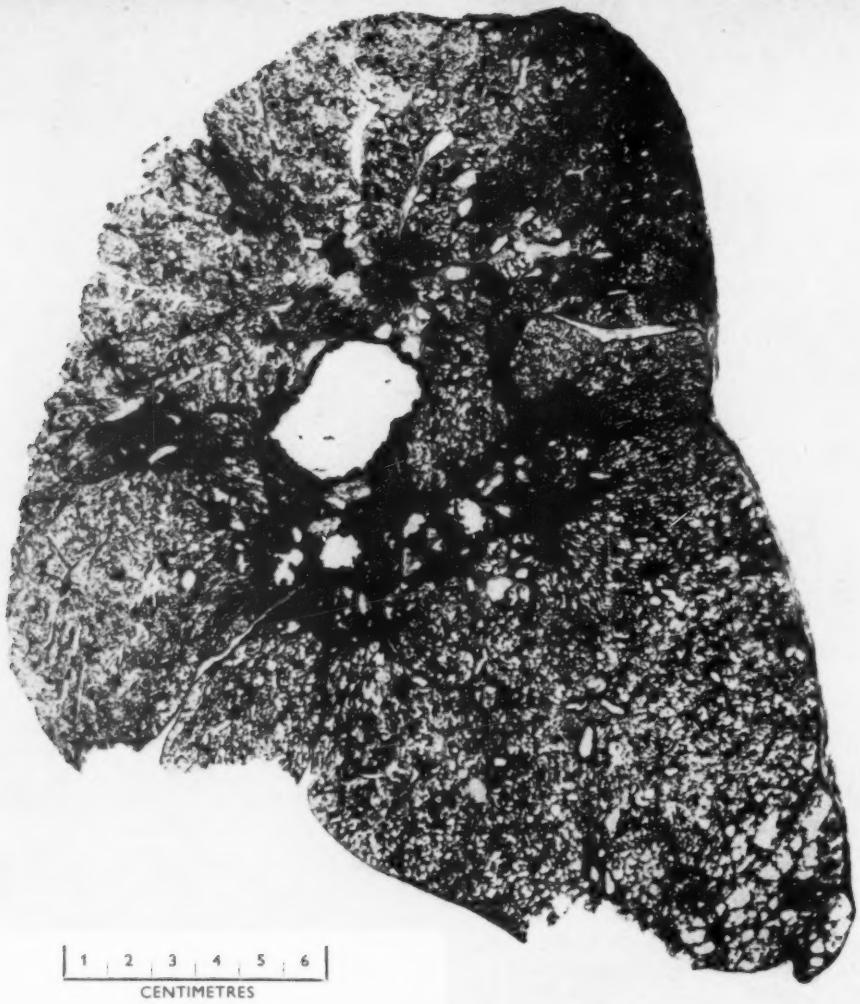

FIG. 6

FIG. 6.—Case 16. Parasagittal thin section of right lung showing a massive fibrotic lesion in the parahilar region with a large central cavity. The remainder of the lung is studded with innumerable small dust foci attended by a severe degree of focal emphysema.

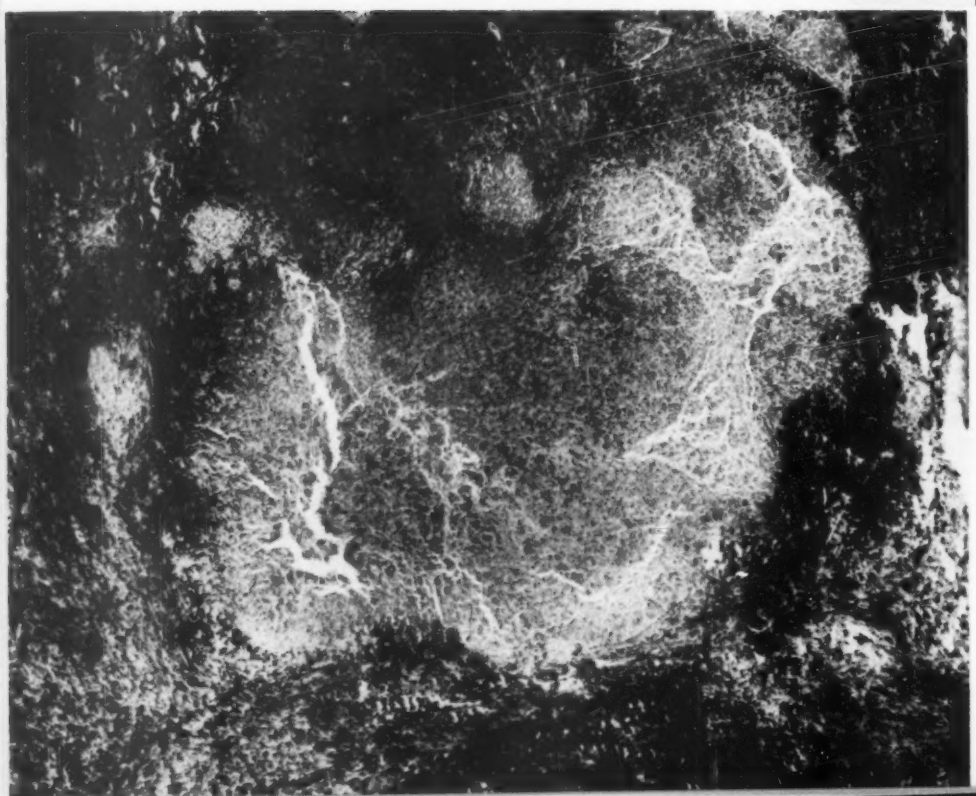

FIG. 7

FIG. 7.—Case 16. A typical example of the sort of necrotic foci which were present in the fibrotic masses. × 38 (reticulin).

FIG. 8.—Case 16. Severe obliterative endarteritis of arteries in wall of a chronically inflamed dilated bronchus within a massive fibrotic nodule. × 80 (Masson).

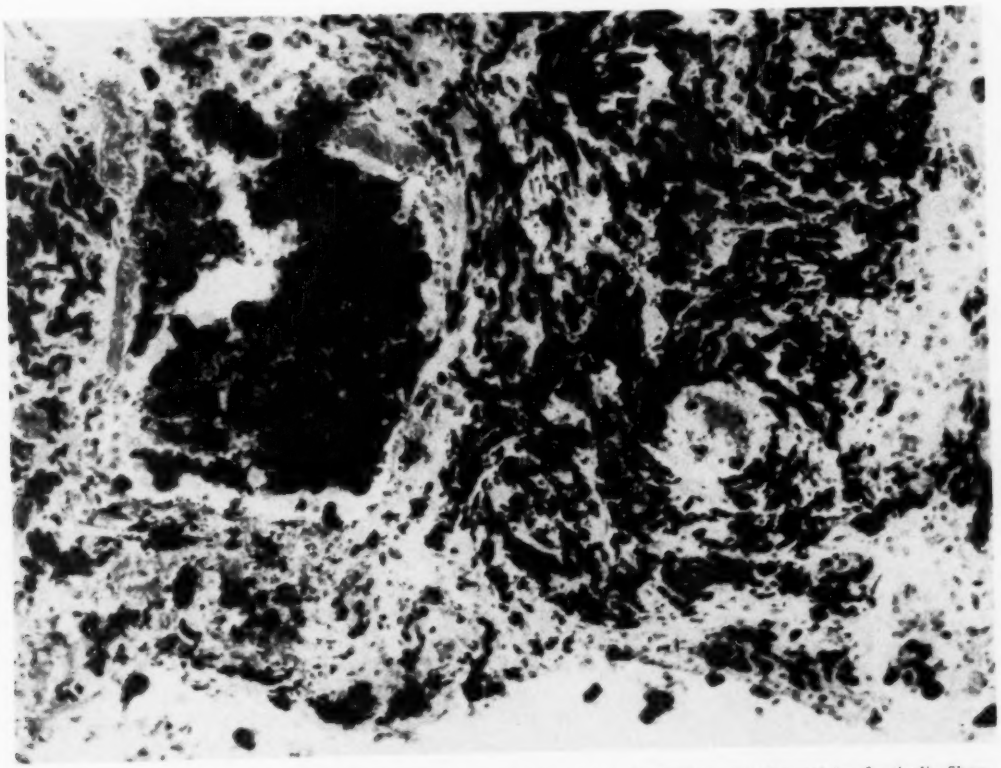

FIG. 9.—Case 17. Focal dust deposit with aggregates of dust particles set in a meshwork consisting mainly of reticulin fibres. The dust within the brochiole is clearly intraphagocytic. × 160 (haematoxylin and eosin).

except broncho-vesicular breathing in the upper zones and the presence of extrasystoles. The chest radiograph showed discrete nodulation evenly distributed throughout both lung fields and extending to the periphery. There was diminished translucency over the left upper zone with a dense opacity above the upper pole of the left hilum. A diagnosis of simple pneumoconiosis accompanied by bronchial carcinoma was made. Treatment by deep radiotherapy and administration of nitrogen mustard was carried out, but his condition progressively deteriorated and he died in June, 1956.

Post-mortem Examination.—The upper part of the left pleural sac was obliterated by dense fibrous adhesions. In the left lung there was a large spherical cancerous mass, 7·0 cm. in diameter, apparently arising from the main bronchus to the left upper lobe. The tumour had invaded the parahilar region of both the upper and lower lobes, and metastatic deposits of carcinoma were present in several enlarged mediastinal lymph nodes. Throughout the remaining parts of both lungs there were scattered moderately numerous soft focal aggregates of black dust. These foci measured up to a few millimetres in diameter and were associated with a slight degree of focal emphysema. A metastatic carcinomatous deposit was present in the left adrenal gland. Other organs showed no notable abnormality.

Histology.—The tumour arising from the left upper lobe bronchus was a small-celled anaplastic carcinoma of oat-cell type. The small dust foci consisted of aggregates of small black particles lying in an inconspicuous meshwork of irregularly disposed reticulin and collagen fibres; associated with the black dust there were occasional doubly refractile particles. In all of the foci there was a preponderance of dust over connective tissue (Fig. 9). Focal emphysema was present in relation to many of the dust foci but was not of great severity.

Lung Dust Analysis

An analysis was made of the lung dust in Cases 15 and 16. The methods were essentially the same as those used for coal-miners' lungs by King, Maguire, and Nagelschmidt (1956), except that portions of the right and left lung were analysed separately for carbonaceous matter which is recorded as "coal". Briefly, "coal" was obtained by dissolution of the dried lung tissue with alcoholic KOH and its amount determined by ashing. Mineral matter was estimated as the acid-insoluble portion of the lung ash prepared at 380° C. Carbon and hydrogen determinations were performed on the coal residues which were also examined by *x*-ray diffraction and the size of the coal particles was determined by electron and optical microscopy. The mineral residues were examined by *x*-ray diffraction and partial chemical analysis.

According to its carbon/hydrogen ratio the "coal" was found to be a mixture of coke and anthracite. The mineral matter consisted of corundum and mullite with traces of mica and quartz (numerical data are given in Table 2). The size distribution of the dust from Case 16 is shown in Table 3 and illustrated in Figs. 10a and 10b, while *x*-ray diffraction diagrams of the mineral matter are given in Fig. 11.

TABLE 2

LUNG DUST ANALYSES OF CASES 15 AND 16

	Case 15		Case 16	
	Left	Right	Left	Right
% *Dried Lung*				
Total dust	32·6	35·4	20·1	23·4
"Coal"	32·3	35·2	19·7	23·0
Mineral residue	0·2		0·4	
Quartz	<0·01		<0·02	
Total SiO_2	0·05		0·13	
Total Al_2O_3	ND		0·10	
Estimated Amounts in Both Lungs (g.)				
Total dust	102·0		74·9	
"Coal"	101·3		73·5	
Mineral residue	0·7		1·4	
Quartz	<0·03		<0·07	

ND = not determined.

TABLE 3

SIZE DISTRIBUTION OF LUNG DUST FOR CASE 16 BASED ON AN ELECTRON MICROSCOPE COUNT OF 882 PARTICLES

Size (microns)	Number (%)	Mass (%)
0·23	5·0	0·026
0·32	12·2	0·1
0·45	10·4	0·3
0·64	14·3	1·2
0·9	21·2	4·8
1·3	17·3	11·25
1·8	13·7	25·6
2·6	5·1	26·9
3·6	0·5	6·76
5·1	0·2	9·6
7·2 to 10·2	0·1	13·5

Discussion

Carbon electrode workers have been scheduled under the National Insurance (Industrial Injuries) Act since 1951 and it is clear from the findings in the clinical survey detailed above that, in the past at any rate, there has been a considerable risk of the development of pneumoconiosis in this employment. Nine cases of pneumoconiosis were found in the group of 15 men surveyed, and in four of these it was of the complicated variety. It is probable that the incidence of dust disease of the lungs in carbon electrode makers, in the factory with which we are concerned, will fall considerably and eventually disappear as a result of the more effective preventive measures which have now been instituted.

Of the three cases which came to necropsy the third (Case 17) is of interest in so far as the lungs showed simple pneumoconiosis with focal emphysema, resembling in every way the corresponding condition in coalworkers. Obviously it would be unprofitable to discuss the question of a relationship between pneumoconiosis and concomitant bronchial carcinoma on the basis of one such case. The findings in Cases 15 and 16 demonstrate that carbon electrode makers are subject to a form of pneumoconiosis closely resembling in its gross and

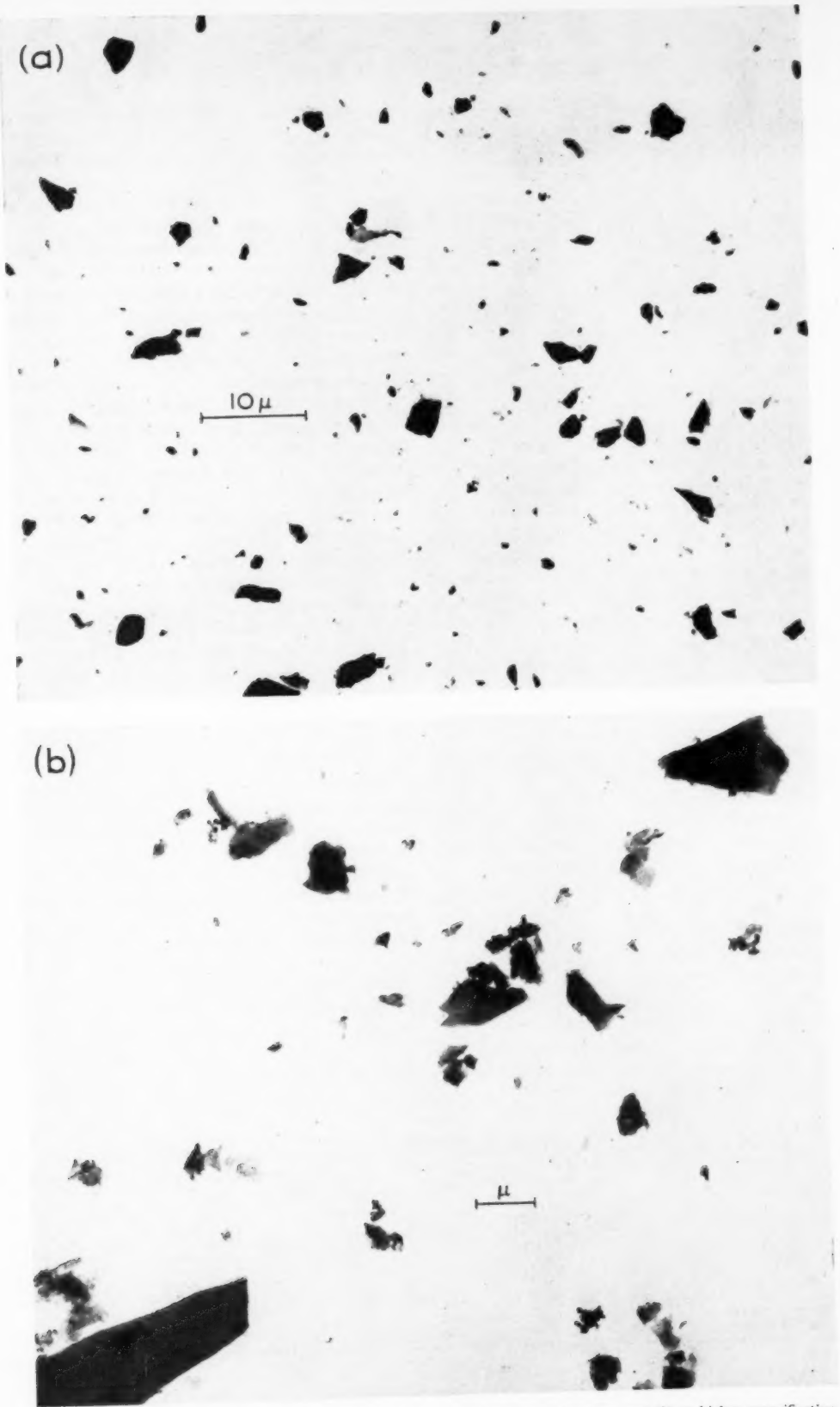

FIG. 10.—Electron micrographs of lung dust of Case 16: (*a*) at lower magnification, and (*b*) at higher magnification.

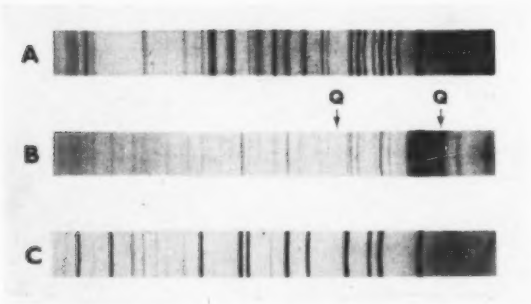

FIG. 11.—*X*-ray diffraction diagrams of (A) mullite, (B) lung residue (acid-washed ash) of Case 16, and (C) corundum.

in its histological appearances the condition of progressive massive fibrosis in coalworkers. In this respect alone these cases are of some importance, but their main significance lies in the light which they throw on the aetiology of massive fibrosis in coalworkers.

The aetiology of massive fibrosis in coalworkers is an unsolved problem and the several opposing views in the literature have been succinctly summarized by Cochrane, Miall, Clarke, Jarman, Jonathan, and Moore (1956). The two main theories are spoken of as the "silica" and "tuberculosis" theories. According to the "silica" theory the confluence and collagenization of coal dust macules, due somehow to the action of silica contained in them, can result in massive fibrosis. The "tuberculosis" theory suggests that the fibrotic masses represent tuberculous lesions modified by the presence of coal dust. In this country the "tuberculosis" theory undoubtedly has the great majority of adherents and has been strongly supported by Gough and the Cardiff "school" (Gough, 1947; Heppleston, 1951; James, 1954). On the other hand, Di Biasi (1949) and many European pathologists adhere to the "silica" theory.

As the lung dusts of coal-miners and even of coal trimmers always contain some quartz, it has been difficult to disprove the "silica" theory. A comparison can be drawn with the occurrence of massive fibrotic lesions in the lungs of kaolin workers (Hale, Gough, King, and Nagelschmidt, 1956) and of talc workers (Hunt, 1956). But although quartz was absent in these cases, kaolin and talc are plate-shaped silicates very dissimilar to coal dust particles. A search amongst carbon black workers showed early stages of simple pneumoconiosis (Gärtner and Brauss, 1951), but there were no instances of massive fibrosis. Likewise Meiklejohn (1958) found no cases of massive fibrosis among carbon black workers engaged in the manufacture or handling of "nearly pure carbon". In a group of workers handling "mixed carbon", which contained a small amount of mineral impurity, there was one who showed radiological evidence of complicated pneumoconiosis (category 2A). Vaccarezza (1958) has recently described a case of massive pneumoconiosis in a man who had been engaged in shovelling charcoal for several years. The evidence was again purely radiological.

The results of lung dust analyses in our Cases 15 and 16 with massive pneumoconiosis are noteworthy in relation to the validity or otherwise of the "silica" theory. The amounts of carbonaceous matter (coal and coke) found in the lungs were large, although similar figures have been observed in massive fibrosis of South Wales coal-miners, screen workers, and trimmers (King and Gilchrist, 1945; King, *et al.*, 1956). The range of coal percentages of the dried lung in such cases has been from 6 to 29·5. As compared with these, the proportion of mineral matter to coal was considerably lower in the present cases: quartz was almost completely absent and the silica found by chemical analysis was mainly accounted for by mullite and mica which, in the amounts found, are very unlikely to constitute a dust hazard to the lungs. In Table 4 our results are compared with those of lung dust analyses in cases of massive fibrosis of coalworkers from South Wales. The present cases can be explained as a variety of silicosis only if it is further assumed that the quartz which caused it had disappeared from the lungs by solution or lymph transport. We consider that this is very unlikely.

TABLE 4

LUNG DUST ANALYSES OF MASSIVE FIBROSIS OF COALWORKERS WITH MORE THAN 20% COAL (PERCENTAGE DRIED LUNG) COMPARED WITH PRESENT TWO ELECTRODE MAKERS (CASES 15 AND 16)

Occupation	Percentage Dry Lung				Reference
	Coal	Non-coal	Quartz	Total Silica	
Fireman	29·5	1·91	0·50	1·22	King, Maguire, and Nagelschmidt (1956)
Screen worker	26·6	1·78	0·27	0·95	King and Nagelschmidt (1945)
Anthracite collier	26·0	3·05	0·45	1·62	King and Nagelschmidt (1945)
Anthracite collier	23·8	1·53	0·31	0·86	King and Nagelschmidt (1945)
Anthracite collier	23·6	1·20	0·18	0·64	King and Nagelschmidt (1945)
Trimmer	20·8	0·83	0·12	0·44	King and Nagelschmidt (1945)
Carbon electrode maker	21·5	0·4	<0·02	0·13	Present paper (Case 16)
Carbon electrode maker	33·8	0·2	>0·01	0·05	Present paper (Case 15)

A case of massive fibrosis in a graphite grinder, reported by Rüttner, Bovet, and Aufdermaur (1952), is very similar to our Cases 15 and 16: there were large fibrous masses and nodular lesions in the lungs with no gross or microscopical evidence of tuberculosis, and analysis of the lung dust showed the presence of graphite and carborundum but no quartz. No figures were given for the percentage dust content of the lungs nor for the total amount of dust present. Also relevant to our work are the findings of Koelsch (1952), who described advanced stages of pneumoconiosis in carbon electrode makers handling carbon or anthracite with only a trace of silica, mostly in the form of silicates. Diagnosis in these cases was radiological and there was no reference to pathological examination. We believe that our Cases 15 and 16 demonstrate better than any cases hitherto recorded that the presence in the lungs of large amounts of dust which are virtually free from quartz can cause a form of dust disease entirely similar to coalworkers' pneumoconiosis, with small focal and massive fibrotic lesions. The lung dust in our cases was a mixture of coke and coal and the fact that Case 16 may have inhaled some coal dust during his employment as a blacksmith does not alter the significance of the findings.

In Case 16 small foci of acute tuberculous caseation were seen histologically within the areas of massive fibrosis. Although none of these foci was associated with a tuberculous type of tissue reaction their tuberculous nature was confirmed by the demonstration of tubercle bacilli within them. By culture and animal inoculation it was proved that these tubercle bacilli were fully virulent. From their acute nature it is evident that these frank tuberculous lesions were of terminal occurrence, but it does not necessarily follow that they were the result of a secondary exogenous infection. It may well be that they represented an exacerbation, due presumably to lowered resistance, of a pre-existing infection. If this was so, the finding of tubercle bacilli in the lungs of our Case 16 is additional evidence in favour of the "tuberculosis" theory of the causation of massive fibrosis, especially in view of the virtual absence of quartz. One of us (A.T.D.), however, holds the view that a major factor in the production of massive fibrosis in coalworkers is the occurrence of atelectasis of the alveoli between discrete lesions, thereby forming a dense, airless mass which, due to changes in the vessel walls, is ill supplied with blood and in which infection and necrosis readily occur (Doig, 1956).

This paper is published by permission of the Government departments concerned. We are grateful to Professor J. Gough for the large sections of the lungs of Cases 15 and 16, and to E. S. Nelson and J. Cartwright for help with the chemical analyses and electron microscopy. Figs. 1 to 9 were prepared by Mr. G. Kerr. Crown copyright is reserved on Figs. 10 and 11.

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THE EFFECT OF DIFFERENT CONCENTRATIONS OF SILICIC ACID AND SILICA DUST ON THE BIOSYNTHESIS OF COLLAGEN IN TISSUE CULTURES

BY

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Tissue cultures of fibrogenic cells which form collagen *in vitro* are a valuable model for quantitative study of the mechanism of this cellular function as well as of problems relevant to pneumoconiosis. We have found a pronounced stimulation of collagen formation in tissue cultures of embryonic chicken lung by silicic acid in a concentration of 0·005M in the medium. Higher concentrations (0·01M) were inhibitory as were quartz dust particles of 50 to 70 mg. per culture tube, which, during the eight days of incubation, liberated silicic acid in concentrations of an inhibitory order into the culture medium. A low concentration (0·001 M) of silicic acid or of silica dust (5 mg.) was ineffectual as was an inert dust (TiO_2) in a high concentration (50 mg.). Evidence is presented that the stimulatory effect of silicic acid is due to a direct stimulation of postulated enzymatic systems taking part in fibrogenesis. Estimation of dioxyribonucleic acid in the cultures indicated that the number of cells was similar in controls and in cultures with increased and reduced collagen content.

The methods of tissue culture have been used in many studies in pneumoconiosis. In none of these studies have the effects of substances stimulating fibrogenesis *in vivo* been investigated by measuring directly the synthesis of collagenous proteins *in vitro*, as indirect criteria only have always been used. The phagocytic activity or the degenerative changes as seen in morphological or metabolic impairment of explanted animal cells brought into contact with toxic dust particles have been recorded. Several more or less precise phagocytic indices and dust toxicity tests showing some differences in cellular reactions to inert and toxic dust particles have been designed (Luhr, 1958). In many instances these criteria were shown to be somewhat unspecific and not too reliable (Belt, Friedmann, and King, 1947) though in some recent studies better results were reported (Marks, Mason, and Nagelschmidt, 1956; Marks and Mason, 1956).

Our present experiments are based on the known ability of explanted fibroblastic cells to continue the synthesis of collagenous structures in tissue culture (Porter and Vanamee, 1949). We measured the biosynthesis of collagen in cultured embryonic chick lung tissue quantitatively under the influences of toxic and inert dust particles and of colloidal silicic acid, a potent stimulator of fibrogenesis in other experiments (Siehoff and Antweiler, 1956; Jötten and Klosterkötter, 1958).

Materials

Tissue Cultures.—Known amounts (about 100 mg. wet weight) of lung tissue from 15- to 17-day-old chicken embryos were explanted as fragments in roller tubes on a film of hen plasma in a medium consisting of 40% tyrode solution, 40% horse serum, and 20% native chicken embryonic extract. One hundred units of penicillin and 100 μg. of streptomycin were added on 1 ml. of medium. The cultures were incubated at 38°C. and rotated 60 times an hour. The medium was not changed during eight days of incubation.

The first determination of collagen was done in incubated controls and then after four and after eight days of incubation. In the last two series of experiments hydroxyproline was determined after eight days of incubation only.

Determination of Collagen.—In saline-washed cultured tissue collagen was determined in individual tubes after acid hydrolysis with 6N hydrochloric acid for four hours at 140°C. In neutralized hydrolysate the amount of hydroxyproline as an indicator of the amount of collagen was determined by the method of Neuman and Logan

(1950) in Martin's and Axelrod's modification (1953). Every value represents the average of 10 determinations. Dioxyribonucleic acid was isolated by the method of Hull and Kirk (1950) and determined spectroscopically at 2·600Å (Scott, Fraccastoro, and Taft, 1956).

Silica Dust.—Silica dust shown by *x*-ray diffraction to contain 99·8% of pure SiO_2 was used. The particles of the dust prepared by fractionated sedimentation contained practically monodispersed dust of 0·6 to 0·8 μ.

Colloidal Silicic Acids.—A dilute solution of sodium metasilicate was neutralized with hydrochloric acid and dialysed against tap water. The concentration of silicic acid was verified gravimetrically as SiO_2.

Method of Estimating Solubility of Quartz Particles in Culture Medium.—The solubility of 60 mg. quartz particles, 0·8μ, was estimated gravimetrically in 10 ml. of tissue culture medium (40% horse serum, 20% chicken embryonic extract, and 40% tyrode solution) in roller tubes used in the tissue culture experiments. Eight samples with and four without quartz were rotated for eight days at 37° C. and then centrifuged through sintered glass.

The gravimetric analysis was performed in 7 ml. of the supernatant in porcelain and platinum containers, samples without quartz being used as controls of the organic ash values of culture medium. The final values of silicic acid dissolved in the medium from quartz were obtained by subtracting the organic ash weight in the control tubes without quartz from the weight measured in the tubes with quartz.

Inert Dust.—Inert dust was commercially available as TiO_2. To one tissue culture tube, approximately 50 to 70 mg. of SiO_2 or TiO_2 was added. Silicic acid was added in three different concentrations in tyrode solution in the proportion of 0·5 ml. to 9·5 ml. of medium. Its final concentrations in the medium were 0·001M, 0·005M, and 0·01M respectively. Control cultures had 0·5 ml. of tyrode solution only.

Results

In five independent experiments, we first tested the ability of our culture system to produce collagen under our experimental conditions. The fibrogenic cells of chicken embryonic lung produced collagen, as shown in Fig. 1. The amount of hydroxyproline after eight days of cultivation was significantly higher than before incubation.

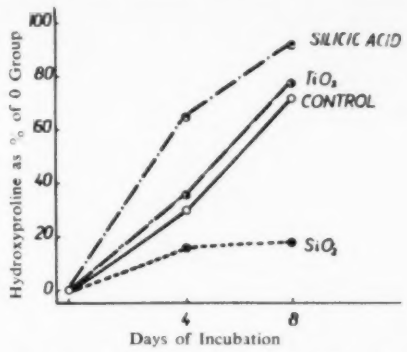

FIG. 1.—The influence of silicic acid, TiO_2, and SiO_2 on the amount of hydroxyproline in tissue cultures.
The concentration of silicic acid was 0·005M; TiO_2 and SiO_2, 50 to 70 mg. per tube.

Further experiments were designed to study the effects of an inert dust (TiO_2), a toxic dust (SiO_2), and a known substance with fibrogenic activity (silicic acid) on the biosynthesis of collagen occurring in our experiment *in vitro*. There was no difference in the amount of hydroxyproline after eight days of incubation between the control group and the cultures incubated with 50 to 70 mg. of TiO_2. The cultures incubated with the same amount of the silica dust showed a marked inhibition of collagen formation, and in the cultures incubated with 0·005M silicic acid the formation of collagen was significantly stimulated (Fig. 1).

Table 1 shows the amount of dioxyribonucleic acid in cultures of all series after eight days of incubation. There was no significant difference in the amount of this substance, indicating that cellular multiplication was the same in all our culture groups. Thus the differences in the amount of collagen are probably due to a difference in the amount of extracellular substances in different experiments rather than to differences in cellular multiplication.

TABLE 1
SUMMARY OF RESULTS

Duration of Incubation (days)	0		4			8				
	†	Hydroxyproline (μg./100 mg.)	†	Hydroxyproline (μg./100 mg.)	Changes in % of Controls in O	†	Hydroxyproline (μg./in mg.)	Changes in % of Control in O	†	D.N.A. (ug./100 mg.)
Controls	38	14·8 ± 0·18	16	19·2 ± 0·3	30	40	25·5 ± 0·4	72	14	103 ± 3·5
Silica dust, 50 to 70 mg. per tube		—	10	17·2 ± 0·4	16	20	17·5 ± 0·4	18*	10	104 ± 3·8
Silica dust, 5 mg. per tube		—	—	—	—	8	23·5 ± 0·9	59	—	—
Silicic acid, 0·01 M	—	—	10	17·5 ± 0·4	18	10	17·9 ± 0·5	21*	—	—
Silicic acid, 0·005 M	—	—	8	24·4 ± 0·4	65	13	28·4 ± 0·3	92*	13	108 ± 3·6
Silicic acid, 0·001 M	—	—	—	—	—	10	26·0 ± 0·3	76	—	—
TiO_2, 50 to 70 mg. per tube	—	—	10	20·1 ± 0·4	36	10	26·3 ± 0·3	78	8	99 ± 4·1

*Change significant at 1% level in relation to control values.
†No. of roller tubes.
Variability is given by the standard error of the mean.

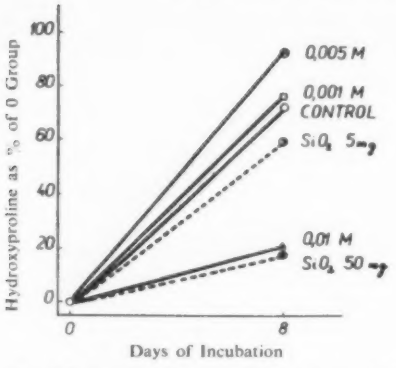

FIG. 2.—The influence of different concentrations of silicic acid and quartz on the amount of hydroxyproline in tissue cultures.

Further experiments were made to elucidate the apparent incongruity of results regarding the stimulation of fibrogenesis brought about by silicic acid and its marked inhibition by silica dust. We therefore investigated in repeated independent experiments the effect of three different concentrations of silicic acid on collagen formation in our tissue cultures (Fig. 2). In a concentration of 0.005M, silicic acid stimulates significantly the production of collagen measured by an increase of hydroxyproline. In a higher concentration of 0·01M silicic acid has an opposite effect and acts as an inhibitor of collagen synthesis. In the very low concentration of 0·001M, silicic acid has no effect. These results are in agreement with the finding of inhibitory effects of silica dust on collagen synthesis. In the amount used (60 mg.), dust particles of 0·8 μ dissolve in serum during eight days and give a solution of silicic acid, the concentration of which is of the same order as the inhibitory concentration in our experiments.

Table 2 gives the values of silicic acid dissolved in tissue culture medium, and Table 1 summarizes all our results.

If our explanation of the mode of action of crystalline quartz on the fibrillogenetic activity of fibroblasts be correct, lower SiO_2 concentrations would not inhibit the biosynthesis of collagen in tissue culture. We therefore investigated the synthesis of hydroxyproline containing substances in cultures with 5 mg. and 50 mg. of crystalline SiO_2 added to the medium and in untreated controls. In control cultures there was an increase of 71% of unincubated blanks; in cultures with 5 mg. of SiO_2, there was no significant difference from control values (53% increase of collagen) whereas in the cultures treated with 50 mg. of SiO_2 the synthesis of collagen was again significantly inhibited ($P < 0, 0{\cdot}1$) (Fig. 2). A further demonstration of this hypothesis is the ineffectiveness of silica dust in low concentration (5 mg. per culture tube).

Discussion

The first quantitative study of collagen synthesis in tissue culture was published by Gerarde and Jones (1953). These authors reported a great (800%) increase of collagen after 12 days of cultivation differing somewhat from the conditions in our experiments. Recently, Hulliger, James, and Allgöwer (1957) obtained a 100% increase of collagen in tissue cultures after 10 days of cultivation. These results are in good agreement with our finding of an 80% increase of collagen after eight days of cultivation. In absolute values, this represents an average of 15 μg. of hydroxyproline in 100 mg. of wet lung tissue of 15- to 17-day-old chicken embryos and 25 μg. after eight days of cultivation.

The ability of explanted fibrogenic cells to produce collagenous proteins in tissue culture is thus established, and this experiment *in vitro* may serve as a valuable model for the study of factors which stimulate collagen formation. Such a technique may be used with advantage for investigations concerned with the mechanism of collagen synthesis as well as for research relevant to the fundamental problems of pneumoconiosis.

In this part of our work we used the tissue culture experiments to study direct effects of silica dust and silicic acid on the formation of collagen. In an appropriate concentration, silicic acid has a pronounced stimulating effect on collagen synthesis in explanted lung tissue. In a high concentration, silicic acid acts as an inhibitor of this function of fibrogenic cells while in a low concentration its fibrogenic activity is lost. James and Marks (1956) call attention to the fact that silicic acid in concentrations higher than 1·67 to 2·67 M is in solution in a polydispersed

TABLE 2
SOLUBILITY OF QUARTZ PARTICLES IN CULTURE MEDIUM

	Amounts of SiO_2 in mg./10 ml. of Medium				
	I	II	III	IV	Average
Porcelain crucible	25·4	26·6	23·0	27·9	25·7 ± 1·04*
Platinum crucible	29·2	26·4	26·2	22·5	26·2 ± 1·37*

26 mg. of SiO_2 corresponds to $4{\cdot}3 \times 10^{-3}$ M silicic acid.
*S.E. of the mean.

state, while in lower concentrations it dissociates into monomeric form. We did not attempt to analyse these problems in the work reported here. Our experiments amassed evidence that the inhibitory effects of a given amount of silica dust on collagen synthesis in tissue culture are due to its solubility in a serum medium, where a concentration of silicic acid shown to act as an inhibitor of collagen synthesis is formed by dissolution of the dust during the incubation period. Further known toxic effects of ingested silica particles on phagocytic cells are not considered in the present study, showing clearly the ability of silicic acid in sufficient concentration to suppress collagen production with no particles present. An inert dust (TiO_2) in the same amount per culture tube as the silica dust was ineffective.

The increase of collagen is not due to an increase in the number of cells, for the amount of dioxyribonucleic acid indicating the extent of cellular multiplication, does not differ from the controls. The same is true for the experiments where an inhibition of collagen synthesis under the influence of a high concentration of silicic acid or of silica dust was found without a change in the amount of dioxyribonucleic acid.

Our results lead us to the conclusion that silicic acid in adequate concentration stimulates the activity of some enzymatic system (or systems) of the cells which take part in collagen synthesis and was postulated by Jackson, Fitton, and Smith, (1955) and by Jackson and Smith (1955, 1958) on the basis of their experimental work. If this hypothesis be correct our results would bring the first evidence of a stimulation of enzymatic activity by silicic acid. The nature of this activity is unknown, as most of the enzymes tested are inhibted by this substance (Kind, King, Pash, Roman, and Schmidt, 1954; King, Schmidt, Roman, and Kind, 1956; James and Marks, 1956).

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STUDIES ON THE NATURE AND AETIOLOGY OF RESPIRATORY DISABILITY IN WITWATERSRAND GOLD-MINERS FREE OF RADIOLOGICAL SILICOSIS

BY

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In an investigation into the cause of symptoms in gold-miners who have no radiological silicosis, the relationship of dyspnoea and physiological disturbances to dust exposure was examined. Forty-five subjects, aged 41 to 45 years, with normal chest radiographs and long service underground were chosen for study from the population of miners past and present. Thirty-four men only were tested, but the validity of the sample was checked by comparison with a similar group of miners reported previously.

Each individual's dust exposure was estimated in "particle-hours". A detailed history, including smoking habits, was followed by a clinical examination and a battery of lung function tests in each case.

No significant relationship was found between dyspnoea and dust exposure or smoking. However, a negative correlation was observed between dust exposure and effort tests, implying that exercise capacity appeared best in those men whose dust exposure was greatest. Possible reasons for this finding are discussed.

On the other hand, dyspnoea did correlate with airway obstruction and hyperventilation on effort, indicating a physiological rather than a psychological basis for the symptoms. Further, the higher incidence of cough, sputum, and rhonchi in the more disabled subjects suggested that chronic bronchitis might be the basis of their symptoms, but the cause of the bronchitis remains to be identified. It seems that dust exposure alone was not the cause, but the findings do not exclude the possibility of its being related to the occupation of mining with stresses such as inhalation of fumes and rapid changes in temperature, humidity, and altitude.

In recent years medical men concerned with the health of miners have become increasingly aware of the poor correlation between the degree of disability of the miner and the radiological evidence of pneumoconiosis (Pemberton, 1956; Newell and Browne, 1955). In the case of the Witwatersrand gold-miner interest has centred on those miners who are obviously disabled but whose chest radiograph shows no signs of dust disease. There appear to be three possible causes of disability (or any combination of these) in such a miner:—

(1) Psychogenic factors producing exaggeration of symptoms (including malingering);

(2) Presence of other lung disease, *e.g.*, bronchitis, bronchospasm, or emphysema;

(3) Presence of dust fibrosis as yet radiologically undetectable.

Undoubtedly a small number of men fall into the first group. However, a study of the lung function of Witwatersrand gold-miners selected at random on radiological grounds left about 30% of the subjects studied unassigned to either the normal or abnormal lung function classes (Becklake, du Preez, and Lutz, 1958). Investigation of this ambiguous group obviously required study of the second and third possibilities listed above.

In a previous investigation comparing radiologically normal miners with railway workers (Zwi and Becklake, 1958), the incidence of bronchitis and emphysema (using the criteria of Pemberton, 1956)

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was found to be no different in the two groups. Consistent differences in the lung function tests of the two groups were not found, though maximum voluntary ventilation was reduced and non-elastic resistance increased in the miners.

The present study was designed to investigate the third possible cause of disability in these radiologically normal miners by studying the relation of symptoms and physiological disturbances to the duration and severity of dust exposure.

Methods

The cases required for study in the present series were thus miners of similar age with no radiological signs of pneumoconiosis (cases with increased lung markings were also excluded), but among whom there was considerable variation in the amount of dust exposure. Length of service on rock-breaking jobs provided the index of dust exposure on which the men were selected.

An annual examination (clinical and radiological) at the Pneumoconiosis Bureau, Johannesburg, is compulsory for all working miners, for all retired miners who wish to retain the right to mine, and all men in receipt of partial compensation for dust disease until such time as they are in receipt of maximum compensation. From the Bureau records of men examined between December, 1955, and May, 1956, a list was compiled of all men between 41 and 45 years of age whose chest radiographs were considered normal. These cases were then sorted according to the record of rock-breaking service, and 45 men were selected at random from those available. The radiographs were read independently by three observers; only those agreed as normal by all three were accepted, and they were then checked against the reading of the man's previous radiograph. Thirty-four men were finally tested (Table 1A), none of whom had mixed service, *i.e.*, their mining experience was restricted to goldmining.

TABLE 1A

THE PLAN OF THE STUDY

Claimed Rock-breaking Service (years)	Number of Men Selected	Number of Men Tested
<1	9 cases (254)	4 cases
5 to 5½	9 cases (22)	6 cases
11 to 11½	9 cases (10)	6 cases
14 to 14½	9 cases (16)	9 cases
17 to 17½	9 cases (12)	9 cases
Total	45 cases	34 cases

The number in parentheses is the total number of cases in the particular population from which the sample was drawn at random.

Cases were rejected for the following reasons:—Three would not cooperate, two had moved to distances over 250 miles from Johannesburg, one had severe complicating angina pectoris, one a disabling back injury, and one could not be traced; in one, service records could not be accurately computed because he had served in a mine where the records before 1942 had been destroyed by fire, and two had worked at a Government miners' training school where no accurate service records were kept.

Since the Bureau records of a miner's service were based on the miner's own statements and were generally considered inaccurate, service records of each man were then checked against those held by the Chamber of Mines for number of shifts worked underground and number of shifts on rock breaking. These can be considered accurate since it was on these records that the man's pay was based, rock breaking being more highly paid than other underground work. In some instances the difference between the miner's statement of his service on rock breaking and that of the Chamber of Mines was considerable. Unfortunately, the accurate assessment of shifts worked in rock-breaking jobs could not be made before selection for study, so the number of subjects tested in each group of rock-breaking service was not as evenly distributed as was planned (Table 1B).

TABLE 1B

TESTED CASES GROUPED ACCORDING TO CONFIRMED ROCK-BREAKING SERVICE

Confirmed Rock-breaking Service (shifts)	Number of Men Tested
0 to 999	6 cases
1,000 to 1,999	4 cases
2,000 to 2,999	6 cases
3,000 to 3,999	9 cases
4,000 to 4,999	5 cases
5,000 or more	4 cases
Total	34 cases

A more accurate estimate of the dust exposure of each man was attempted using information provided by Mr. R. S. J. du Toit, of the Government Mining Engineer's Office, which has published records of konimeter counts in all scheduled mines since 1931. It was calculated in "particle-hours", the product of the hours of a man's underground service and average konimeter count* in scheduled mines for the particular years of his service. Fig. 1 (reproduced from du Toit, 1958) shows average levels of dustiness in different parts of mines for each year from 1931 to 1955.

A careful clinical history was taken in each case with emphasis on respiratory symptoms and details of smoking habits. A man was considered a smoker if he had smoked regularly for one year; the number of cigarettes was noted in tens, *e.g.*, one to 10 noted as 10, 11 to 20 as 20. One ounce of pipe tobacco per week was considered equal to four cigarettes a day (Doll and Hill, 1950). Dyspnoea was graded on the scale suggested by Fletcher (1952). A full clinical examination was carried out on each subject by one of us. In addition the records of previous annual examinations at the Pneumoconiosis Bureau were reviewed to note the number of occasions on which rhonchi had been reported. The average age of the group was 44 years, and recruits must be 17 years of age to start underground work, so that 27 annual examinations would be the maximum number expected for men of this

*Konimeter count represents incombustible, acid-insoluble particles at a magnification of ×150 under dark field illumination.

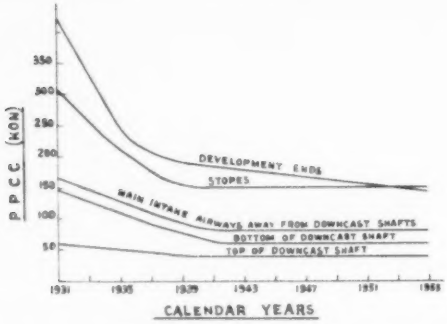

FIG. 1.—The curves are based on the results recorded by government inspectors of mines during routine inspections. Allowance has been made for the altered techniques introduced after 1931. The konimeter counts (in particles/ml.) include particles ranging in size from about 0.3 to 5μ. About 30% of the count is constituted by particles from 1 to 5μ.

age. However, between 30 and 40 records were available for most cases, indicating that many men had undergone several extra examinations during their mining careers, presumably because of complaints about their health.

Lung function tests were carried out using the methods previously described by Becklake and others (1958). Measurements of lung volume, maximum voluntary ventilation (M.V.V.), compliance, and non-elastic resistance were made with the subject seated. Lung volume subdivisions, M.V.V., and the ventilation volumes were expressed at B.T.P.S. Age was recorded to the nearest year, height with the subject in socks, weight with light clothing.

Results

In Table 2 the physical characteristics of the individuals studied are shown, and in Tables 3 and 4 the results of the physiological tests are presented. In order to check the validity of the sample, the results obtained in the present series are compared with those obtained in this laboratory previously on a similar group of miners between 41 and 50 years of age (Zwi and Becklake, 1958). The previous group was selected at random from the Bureau records on the basis of age and a normal chest radiograph. It is of interest to note that the mean age of the previous group was 45 years, and that of the present group is 44, although the age range of the present group is 41 to 45 years. Mean values for the individual tests and lung function scores in the two series are remarkably similar. (Using Student's t test there were no significant differences between the two series at the 5% level.)

The data were next examined to see if it could be shown that either grade of dyspnoea (a subjective measure of pulmonary performance) or any physiological tests (measuring function objectively) showed a relationship with estimated dust exposure.

It will be seen in Table 5 that neither grade of dyspnoea, nor the physiological test score, nor any of the tests done at rest could be shown to correlate significantly with dust exposure estimated either as particle-hours or as shifts on rock breaking. However, a negative correlation was observed between both estimates of dust exposure and the two tests of effort, *i.e.*, ventilation equivalent for O_2 during effort requiring 1 litre of O_2 per minute, and exercise ventilation at a standardized effort of 350 kg.-m. per minute. These relationships imply that for a particular grade of effort the ventilation was lower in the men with the most dust exposure, the reverse in fact of what had been expected. Scrutiny of the full battery of test results in each individual makes the possibility that lower ventilation was due to abnormal lung function most unlikely.

It must be concluded, therefore, that neither grade of dyspnoea nor any of the objective measurements of lung function made in this study appeared to deteriorate in relation to the degree of dust exposure in radiologically normal miners in the present series. On the contrary, exercise capacity appeared best in those men whose estimated dust exposure was the greatest.

The results were examined from the point of view of the grade of dyspnoea to see whether those miners with breathlessness had any common factor to suggest the cause of their complaint. From Table 5 it will be seen that grade of dyspnoea correlated with certain tests of lung function, namely measurements of airflow (M.V.V. and M.M.F.), of adaptation to exercise (ventilation equivalent for O_2 and exercise ventilation), and the dyspnoeic index. It should be

TABLE 2

PHYSICAL CHARACTERISTICS, MINING SERVICE, AND LUNG FUNCTION SCORE OF MEN STUDIED IN BOTH SERIES

	No. of Cases	Age (years)	Height (cm.)	Weight (kg.)	Surface Area (sq. m.)	Total Mining Service (years)	Rock-breaking Service (years)	Lung Function Score
Present series	34	44·0	176·1	79·9	1·961	18·27	11·15	−10·86
Standard deviation		1·26	6·27	10·25	0·1381	2·439	6·031	5·071
Previous series	10	45·0	175·6	78·5	1·936	17·00	4·60	−10·06
Standard deviation		2·21	5·80	11·40	0·1637	3·070	5·770	2·460

TABLE 3

LUNG VOLUME MEASUREMENTS, MIXING, AND EXERCISE VENTILATION IN PRESENT SERIES AND IN A PREVIOUS COMPARABLE SERIES

	Vital Capacity (V.C.) in Litres	Residual Volume (R.V.) in Litres	Total Lung Capacity (T.L.C.) in Litres	Functional Residual Capacity (F.R.C.) in Litres	R.V./T.L.C. %	F.R.C./T.L.C. %	Mixing Index of Becklake and Goldman (1954) (l./litre F.R.C.)	Oximetry		Ventilation Equivalent for Oxygen (l./100ml. O_2 uptake)		Exercise Ventilation* (l./min.)
								Maximum Fall on Effort (%)	Maximum Rise on Oxygen (%)	At Rest	On Effort Requiring 1 l. O_2/min.	
Present series	4·81	1·94	6·76	3·26	28·5	48·4	3·42	0·60	+ 6·74	3·62	2·93	36·5
Standard deviation	0·627	0·633	0·677	0·812	7·32	8·64	0·759	1·167	1·635	1·019	0·410	4·28
Previous series	4·83	1·93	6·81	3·51	28·2	51·6	3·33	1·34	+ 6·33	4·35	2·93	
Standard deviation	0·753	0·507	0·980	0·737	5·75	8·97	0·558	1·770	1·380	1·420	0·560	

*Hugh-Jones and Lambert (1952).

TABLE 4

WORK OF BREATHING STUDIES IN PRESENT SERIES AND IN A PREVIOUS COMPARABLE SERIES

	Maximum Voluntary Ventilation ($M.V.V._{-F}$)* in l./min.	Maximal Mid-Expiratory Flow (M.M.F.) in l./sec. (Leuallen and Fowler 1955)	At Rest				After Exertion				Fall in Compliance on Hyperventilation (+ 50 breaths/min.)	Mean Resting End-expiratory Pressure (cm. H_2O)
			Compliance (l./cm. H_2O)	Resistance (cm.H_2O/l./sec.)		Breathing (Frequency/min.)	Compliance (l./cm. H_2O)	Resistance (cm. H_2O/l./sec.)		Breathing (Frequency/min.)		
				Inspiratory	Expiratory			Inspiratory	Expiratory			
			(Mead and Whittenberger, 1953)				(Mead and Whittenberger, 1953)					
Present series	145·1	3·21	0·223	2·19	2·98	20·6	0·196	1·83	2·51	28·6	−0·039	−2·254
Standard deviation	35·67	1·010	0·0543	1·051	1·280	3·91	0·0497	0·851	0·943	6·46	0·0332	1·9123
Previous series	147·4	3·12	0·234	2·67	3·02	19·9	0·221	2·01	2·88	24·4	−0·015	−3·550
Standard deviation	33·50	1·060	0·0520	0·770	0·890	4·70	0·0490	0·864	0·746	4·50	0·0440	0·9890

*Terminology recommended by Gandevia and Hugh-Jones (1957).

TABLE 5

CORRELATION COEFFICIENTS OF GRADE OF DYSPNOEA AND ESTIMATED DUST EXPOSURE WITH LUNG FUNCTION SCORE, LUNG FUNCTION TESTS, AND SMOKING

	Grade of Dyspnoea	Dust Exposure Estimated as Shifts Underground on Rock Breaking	Dust exposure Estimated as Particle-hours	Smoking
Grade of dyspnoea	—	0·221	0·239	0·141
Lung function score	−0·085	−0·047	−0·060	−0·071
Individual Tests:				
a. M.V.V.	−0·361*	−0·196	−0·271	0·066
b. M.M.F.	−0·334*	−0·129	−0·023	−0·301
c. Non-elastic resistance	0·300	0·262	0·080	0·136
d. Mixing index	0·065	−0·209	−0·202	−0·200
e. Ventilation equivalent for O_2 on effort requiring 1 l. O_2 per minute	0·328*	−0·420*	−0·312	0·041
f. Minute ventilation for a standard exercise of 350 kg.-m./min.	0·384*	0·357*	−0·343*	0·170
g. Dyspnoeic index	0·428*	0·218	0·254	0·061
Smoking (cigarettes/day)	0·141	—	—	—

*P< ·05

noted that, although these correlations are statistically significant, they are not high. Further, the number of men in whom rhonchi had been found on five or more occasions at the annual routine examination was higher (four out of seven) in the group with grade 3 dyspnoea than in the group with no complaint of dyspnoea (three out of 15), as was the incidence of cough and sputum (Tables 6 and 7).

TABLE 6

DUST EXPOSURE AND LUNG FUNCTION TESTS IN MINERS GROUPED ACCORDING TO GRADE OF DYSPNOEA

	No. of Subjects	Shifts Worked on Rock Breaking	Dust Exposure (particle-hours in millions)	Smoking Habits (cigarettes/day)	Lung Function Score	Dyspnoeic Index (%)	M.V.V.$_F$ (l./min.)	M.M.F. (l./sec.)
Men with no dyspnoea (Grade 1)	15	2371·4	4·11	23·3	−10·55	24·1	158·3	3·44
Standard deviation		1761·20	1·214	17·99	4·386	4·60	34·69	0·902
Men with Grade 2 dyspnoea	12	3168·4	4·56	15·0	−12·58	30·3	139·8	3·34
Standard deviation		1817·06	1·056	11·68	5·833	11·99	36·42	1·073
Men with Grade 3 dyspnoea	7	3240·1	4·76	32·9	−8·60	34·5	126·0	2·47
Standard deviation		1396·48	0·960	13·80	4·699	9·61	28·95	0·879

TABLE 7

INCIDENCE OF CLINICAL FEATURES IN MINERS GROUPED ACCORDING TO GRADE OF DYSPNOEA*

	No. of Subjects	Rhonchi Heard on Five or More Periodical Examinations	Cough	Sputum	History of Chest Illness in Past Three Years
Men with no dyspnoea (Grade 1)	15	3 (20%)	4 (27%)	2 (13%)	4 (27%)
Men with Grade 2 dyspnoea	12	2 (17%)	7 (58%)	3 (25%)	1 (8%)
Men with Grade 3 dyspnoea	7	4 (57%)	7 (100%)	5 (71%)	2 (29%)

*The figures in parenthesis denote the percentage of cases in each group with a particular characteristic.

The grade of dyspnoea was not significantly related to smoking whether compared alone or combined with dust exposure (the multiple correlation coefficients were 0·297 against smoking plus rock-breaking shifts, and 0·303 against smoking plus particle-hours). Smoking alone did not correlate significantly with lung function tests in this series (Table 5), but the smokers had a lower M.V.V. and M.M.F. than the non-smokers (including ex-smokers, all of whom had not smoked for 10 or more years). The mean M.V.V. and M.M.F. of the eight non-smokers was 157 l./min. and 3·58 l./sec. respectively, whereas that of the 26 smokers was 142 l./min. and 3·09 l./sec. These results are similar to those of Higgins (1959), but unlike this author we found no differences in the incidence of bronchitic chest illness, cough, sputum, and wheezing in smokers and non-smokers. However, rhonchi were not recorded in any of the latter, but in six of the former group.

Discussion

In this study of Rand miners without radiological signs of silicosis, no correlation could be demonstrated between degree of breathlessness or physiological tests on the one hand and estimated dust exposure on the other. In so far as the degree of silicosis has been shown to relate to dust exposure in Rand gold-miners (Hatch, 1955; du Toit, 1958), the present findings do not point to early silicosis (as yet radiologically undetectable) as the cause of symptoms in these miners. Is there any evidence to suggest other causes?

Our results indicate a physiological rather than a psychological basis for the symptoms. The grade of dyspnoea was shown to correlate with the extent of deterioration in exercise tolerance (as measured by the ventilation equivalent on effort, or by ventilation at a standard work load). Furthermore, subjective assessment of disability correlated with ventilatory impairment as judged by the M.V.V. and M.M.F. values and the dyspnoeic index (Table 5). Although psychological factors, such as lack of motivation, might lead to both exaggeration of symptoms and poor M.V.V. values in the same subject, it is unlikely that hyperventilation on steady effort could be attributed to the same cause.

On the other hand, these test results would not be inconsistent with the presence of chronic bronchitis as the likely cause of symptoms, a possibility which is suggested by the high incidence of cough and sputum in the more dyspnoeic subjects and the frequent detection of rhonchi at annual clinical examinations (Table 7).

Conclusions should be drawn from these observations with caution. The series tested has been small and only 75% of the men sampled were investigated. However, there is strong support for the validity of the sample in that the results agreed well with the previous series studied. It cannot be deduced that the absence of correlation between dust exposure and subjective and objective estimates of pulmonary disability is conclusive evidence that dust exposure is not the cause of the disability in the men studied. It is not impossible that the very fact of a miner being able to continue rock breaking

over long periods means he is physically very fit and that selection of men with longer rock-breaking service is thus also selection of the fitter subjects. Thus the miners with longest service might initially have had "super-normal" test values compared with which their present values might in fact represent deterioration of function. The negative correlation between ventilation on standard effort and degree of exposure would be consistent with this view.

Neither can it be concluded that the absence of correlation of dyspnoea with estimated dust exposure excludes other mining stresses such as exposure to fumes, or changes in temperature, humidity, and barometric pressure as possible aetiological factors. These factors, if important aetiologically, might result in a correlation between disability and total underground service, a possibility which could not be tested in this study due to the nature of selection of subjects, all of whom had similar periods of total service.

However, if these reservations are borne in mind, this study suggests, as an hypothesis worthy of further testing, that in Rand gold-miners with no radiological evidence of silicosis, disability when present may be the result of chronic bronchitis rather than of early silicosis or psychological factors. Whether such bronchitis is attributable to mining or might have developed in the same individuals had they been otherwise employed, remains to be ascertained. In Britain a relationship between bronchitis and smoking has been demonstrated (Oswald and Medvei, 1955; Higgins, 1959), but in Rand miners there is not yet any conclusive evidence on this point.

In so far as the present study provided no evidence to suggest that disability related to dust exposure in the Rand gold-miner who is free of radiological silicosis, it is in agreement with the work of Newell and Browne (1955) on British coalworkers. Their investigation, covering men between the ages of 15 and 65 with chest radiographs varying from normal to massive fibrosis, examined the significance of dust exposure (measured in years of service on the coalface) in a much wider context. They reached the conclusion that, although proportionately more faceworkers have symptoms than other colliery employees, the proportion with symptoms is not related to the number of years of work on the coalface for men of the same age.

Higgins, Oldham, Cochrane, and Gilson (1956), reporting on Lancashire coal-miners, found no clear relation between bronchitis and dust exposure. Worth, Valentin, Gasthaus, Hoffmann, and Venrath (1955) could find no acute disturbance of respiratory function in 30 coal-miners in the lower Rhine region, after seven and a half hours of underground work in a dusty atmosphere, either clinically, spirographically, or by blood analysis. Our findings support these reports in that they are consistent with the presence of bronchitis as a cause of symptoms in the miner who is free of radiological silicosis, but symptoms do not appear to relate to the degree of dust exposure. However, it is probably not valid to make direct comparison of our results on Rand gold-miners with the results of studies on British and Rhineland coal-miners, since dust concentrations in the latter areas are higher, the size distribution of the dust is coarser, and the mineral composition is different. Also other occupational stresses of mining differ in various countries. These factors are probably of importance in explaining the differences between the studies already referred to and a number of others in the literature which stress the association of dust and bronchitis diagnosed clinically (Dautrebande, 1952, quoted by Higgins and others, 1956) and the acute depressant effects on lung function in normal subjects which follow the inhalation of dust (Dautrebande, Alfrod, Highman, Downing, and Weaver, 1948; DuBois, Alcala, and Dautrebande, 1958). The conflicting nature of views expressed suggests that many other variables may be influencing the response of an individual to dust inhalation.

It is important also to stress that in studies in which dust exposure is assessed retrospectively over many years, the inherent inaccuracies place a severe limit on the validity of the conclusions. To provide a clear-cut answer to the effect of dust exposure on pulmonary function, prospective studies are required in which dust exposure is accurately recorded and pulmonary function is assessed at regular time intervals.

This work was done while the authors were on the staff of the Pneumoconiosis Research Unit of the Council for Scientific and and Industrial Research.

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THE JULY (1959) ISSUE

The July (1959) issue contains the following papers :—

Occupational Lung Cancer: A Review. By Richard Doll.

Biochemical Studies on the Toxicity of Tetraethyl Lead and Other Organo-lead Compounds. By Jill E. Cremer.

Dermatitis in the South Wales Mining Industry: A Report of a Survey of Two Collieries. By Bryan F. Matthews.

Accidents in a Naval Dockyard. By C. P. Collins.

The Acute Toxic Effects of Black Smoke. By R. E. Pattle, G. D. Wedd, and F. Burgess.

Some Hazards in the Manufacture and Use of Plastics. By D. Kenwin Harris.

Patterns of Sickness Absence in a Railway Population. By Cecil Gordon, A. R. Emerson, and Derek S. Pugh.

The Action Exerted by Certain Pneumoconiotic Factors upon the Acid Mucopolysaccharide Contents of Pulmonary Macrophages. By N. Gh. Lupu, Doina Velican, C. Velican, and V. Olinescu.

Miscellanea:

A Case of Cirrhosis and Primary Carcinoma of the Liver in Chronic Industrial Arsenical Intoxication. By S. S. Jhaveri.

Book Reviews.

A number of copies are still available and may be obtained from the Publishing Manager, British Medical Association, Tavistock Square, W.C.1, price 17*s.* 6*d.*

Brit. J. industr. Med., 1959, **16**, 297.

AN ANALYSIS OF SOME OBSERVATIONS OF THERMAL COMFORT IN AN EQUATORIAL CLIMATE

BY

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The analysis is introduced by a brief account of the development of work on thermal comfort. The observations, which are fully described in relation to the interior climates which were experienced, were made in Singapore in 1949-50. The climate of Singapore is typical of the equator, being warm, damp and windless; and the annual variation is almost negligible. Buildings are unheated, of an open type, and shaded from the sun and sky.

A multiple regression equation has been derived, giving the thermal effect on a number of subjects of variations in the air temperature, the water vapour pressure, and the air velocity within the ranges experienced. The implications of the equation are discussed, and a climatic index is derived from it which is similar in definition to the widely used " effective temperature " scale, but shows a better correlation with thermal sensation. The new index is named the Singapore index.

At a further stage the thermal sensation scale is simplified for the purpose of probit analysis. The probit regressions of discomfort due to warmth and cold are separately given in relation to the new index, and are combined to yield a thermal comfort graph from which the optimum is obtained and explored. A comfort chart for the rapid assessment of these humid climates is supplied, and an alternative form of the index equation is given which is more suitable for rapid calculation.

It appears desirable in an equatorial climate to attempt to minimize discomfort by allowing to some extent for individual thermal requirements, and the benefits of a suitable climatic spread within a room are described.

The principal factors governing thermal comfort and discomfort were familiar to the ancients, and Hippocrates (400 B.C.) has left a description of physiological climate in terms of temperature, humidity, wind, and radiation which is still qualitatively valid. However, there remained the triple problem: that of measuring the physical variables with appropriate accuracy, of combining them in a single, manageable, climatic index, and of determining the optimum value of the index for human beings living under specified conditions.

Measurements of the general type required for the solution of this problem began to be made in the seventeenth and eighteenth centuries, but indoor climates, almost as much as opinions about them, were found to be elusive. Under natural conditions climates are not uniform but are variable, and their variability affects comfort. Instruments which are reliable under laboratory conditions are found under natural conditions to be affected by several of the physical variables simultaneously. Human beings are indispensable as subjects, but show marked idiosyncrasy, are semi-permanently affected by the climates to which they are subjected, and themselves often appreciably alter the climate in a room. From the first measurements of the temperature of the ambient air made in Florence and Pekin in the mid-seventeenth century, to the delineation of a suitable set of apparatus for the measurement of an indoor climate by Bedford in the 1930s was a period commensurate with the large amount of development that was needed.

The familiarity of the problem of warming a room, and the immediate availability of a rough and ready solution to it, concealed the scientific difficulties. The room itself contains the four three-dimensional fields, of which two, temperature and humidity, are scalar, but the others, air movement and radiation, are partly vector; none of them is constant or uniform, as a rule, and much of the variation is local,

transient, complex, and interrelated. The climatic measurements, which must often be made under difficult conditions without the refinements of the laboratory, need to represent the changing climatic situation with sufficient, but without excessive or irrelevant detail and with a directness and simplicity that will permit the simultaneous use of human beings as subjects. The presence or absence of thermal discomfort, on the other hand, is a matter of opinion which has not so far been related with certainty to any physiological measurement which can be made on the human subject. The opinions of a number of subjects must therefore be elicited, with care to avoid prejudice, and subsequently submitted to statistical treatment.

In such a situation, it is not surprising that several attempts have been made to find a short cut, either by inventing a single instrument which would measure physiological climate directly, or by devising a universal climatic index which would combine the relevant physical factors. An early comfort meter was the Heberden heated thermometer of 1826; others have been the kata thermometer (Hill, 1914), later used as an anemometer; the globe thermometer (Vernon, 1930), and the eupatheoscope (Dufton, 1932). Climatic indices have included effective temperature (Houghten and Yagloglou, 1923), equivalent warmth (Bedford, 1936), and resultant temperature (Missenard, 1944). Indices of physiological stress have also been devised for use under conditions of extreme discomfort, a matter which is not, however, at present under discussion.

Bedford, in 1936, subjected the available instruments and indices to a crucial test, that of estimating the correlation between their respective indications and the comfort votes of British factory workers, according to a scale he had devised, the votes being carefully elicited in a well-designed interview. The test showed that the available indices for interior climate were no improvement on the plain measurement of the air temperature but the popularity of the established indices seems to have been unaffected. Bedford also obtained a multiple regression equation relating his comfort votes to the physical variables.

The internal climate in a room may be measured adequately and conveniently by means of the simple, self-contained set of apparatus described by Bedford (1946), which consisted of a dry- and a wet-bulb thermometer mounted in a whirling psychrometer, a kata thermometer, and a globe thermometer. The first named thermometers are ventilated by whirling and their readings give the air temperature unaffected by radiation, and the depression of the wet bulb, from which the humidity may be calculated using psychrometric tables and Regnault's equation. The kata thermometer is a thermometer with a very large bulb which is gently warmed, and from an observation of the time it takes to cool over a specified temperature interval, in air at a known temperature, the rate of air movement can be deduced. The globe thermometer is an ordinary thermometer with its bulb enclosed in a large blackened copper ball. The elevation or depression of the reading of this thermometer relative to that of the ordinary dry-bulb thermometer in air moving at a known rate gives a measure of the flux of radiant heat.

The populations of the tropics are peculiarly subject to thermal discomfort, due basically to the warmth of the climates in which they live but often consisting, for secondary reasons connected with the lightness of their clothing and the meagreness of their diet, of a sensation of cold. This fact, coupled with the prevalence of overcrowding in tropical cities, has long been recognized as constituting, in relation to human happiness and even to health, a problem of some magnitude, one which by 1940 was ripe for solution. It was possible at that time to do no more than discuss it, but it was discussed, in particular by the writer and Dr. N. Canton, Health Officer of Singapore. The discussion begun in 1940, was resumed in 1946-7, and as a result a project, planned while on leave in England in 1948, was put into operation in Singapore in 1949-50. The resulting observations, a part only of the original, uncompleted project, have since 1957 been completely analysed and the result is here presented.

The observations are relatively few in number in comparison with those obtained in similar projects in cooler climates, but it appears that with lightly-clothed subjects very large numbers of observations may be less necessary, though they are still, of course, desirable. The results which have been obtained are of adequate precision for a first estimate to be made of the requirements of the population of a low-latitude country. It is hoped that the procedure described may be followed by similar projects, leading to the gradual building up of a realistic climatic index covering other warm climates, and of a body of information regarding the thermal requirements of peoples of tropical nations living under varied conditions.

The Observations

The project from which these data were derived was designed to investigate the indoor climate of Singapore, and the response of the acclimatized population to it under the normal, undisturbed conditions of ordinary daily life. About 20 persons who had long been resident

in Malaya*, all healthy adult males of middle-class status, with an English education, were trained in the use of simple instruments for the measurement of the temperature, humidity, and velocity of the ambient air, *viz.*, the whirling psychrometer and the kata thermometer, and were shown how to keep a laboratory record. They were supplied (Bedford, 1946), with a Casella whirling psychrometer and a small bottle of distilled water; a 100-95° F. plain glass Hicks kata thermometer (also in some cases with a 130-125° F. silvered Hicks kata thermometer) and a stopwatch, a thermos flask, and a small retort stand; a 6-inch diameter globe thermometer and a typed card bearing the thermal sensation scale shown in Table 1.

TABLE 1
SCALE OF THERMAL SENSATION

Overall Thermal Sensation	Code Number
Excessively cold	0
Cold	1
Cool	2
Comfortably cool	3
Comfortable and neither cool nor warm	4
Comfortably warm	5
Warm	6
Hot	7
Excessively hot	8

The observers were asked to record their assessments of their own overall thermal sensation according to the scale, and the subsequent readings of the thermometers and the kata cooling time, at intervals of half an hour for roughly six-hour periods, in their own homes and offices, with as little disturbance as possible to the ordinary daily routine. It was the intention to concentrate on the daily extremes of climate in the early morning and afternoon, and on the known periods of climatic difficulty at the equinoxes.

Readings continued as opportunity offered from May, 1949, to April, 1950, the set of apparatus being passed from one subject-observer to another. The distribution of the observations in time is depicted in Figs. 1a and 1b.

The observers were asked to record any events that might have a thermal significance, such as changes in clothing, in the weather, the opening or closing of doors, the use of fans, sensible perspiration, etc. Dimensioned drawings of the location of the instruments and a description of the premises were added to the record. Simultaneous meteorological observations from Kallang Airport were supplied by the Malayan Meteorological Service.

Activity was light, the observers being occupied mainly in taking the observations. They wore the ordinary informal cotton clothing of warm climates,

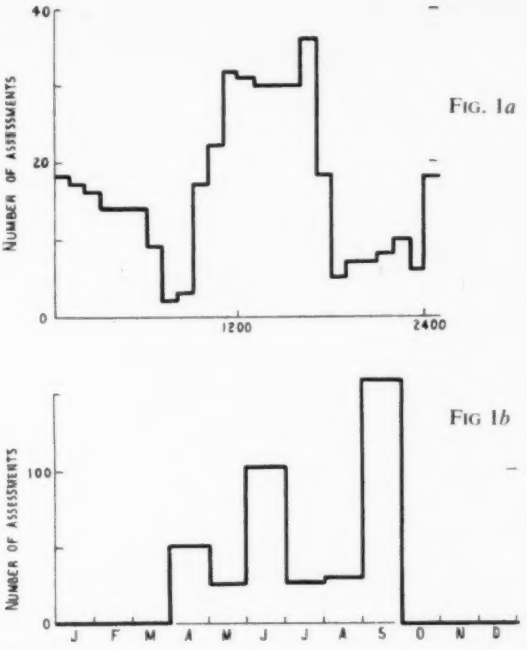


FIG. 1.—The distribution of assessments relative (*a*) to time of day (*b*) to the months of the year.

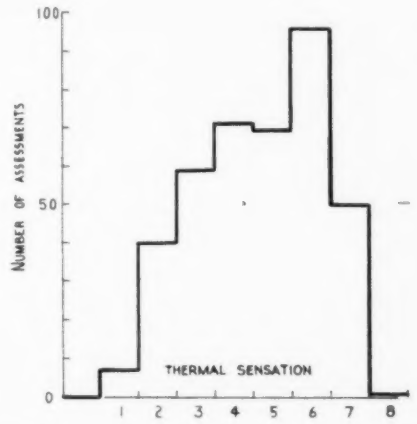


FIG. 2.—The frequency distribution of assessments relative to the thermal sensation scale.

*The subjects chosen as being fully acclimatized were 14 members of the staff of the Singapore Municipal Health Department and six of the Physics Department of the University of Malaya. There were seven Chinese, seven Eurasians of one quarter, or less, of recent European blood, four Europeans, one Indian, and one Malay. The data analysed are from 14 subjects, of whom five were Chinese, seven Eurasian, one Indian, and one European. Two of the Chinese returned only half the average quantity of data and one Eurasian returned three times that quantity. The proportion of Chinese in the city was about twice that in the sample. Subsequent attempts to detect in these data any connexion between race and discomfort were unsuccessful.

The country of origin of nine of the 14 subjects was Singapore or Malaya, of two China, and of two others India and Europe respectively, that of the remaining subject being unrecorded. In seven of the first-named nine cases, both parents were born in Malaya or a neighbouring country and in one case all the grandparents were also.

All but one of the subjects, the European, had been continuously in Malaya for at least 10 years before making the observations, and several had spent their whole lives there. The European had had six months' climatic leave ending two years before the observations began. Before that he had been in Singapore continuously for seven years and altogether for 20.

consisting of a short-sleeved shirt, underpants, trousers, and shoes, with or without socks and necktie, by day: and pyjama trousers, with or without the jacket, by night.

The total number of complete sets of observations, each consisting of a thermal assessment, a wet- and a dry-bulb temperature, a globe temperature, and a kata cooling time, plus other information, was 463. As a preliminary move these were reduced to measurements of the air temperature, the water vapour pressure, and the air velocity by the use of nomograms. The globe temperature was found to agree closely (s.d. $\pm \frac{1}{2}$°F.) with the air temperature and was subsequently ignored. At a later date, 65 sets of observations having been excluded for incompleteness and five for obvious error, the reduction was repeated on 393 sets from 14 observers, using Regnault's formula for the water vapour pressure (assuming a corrected barometric height of 758 mm. of mercury), Bedford's equations (Bedford, 1948) for the 329 observations made on the 100-95°F. kata thermometer, and Koch and Kaplan's equations (Koch and Kaplan, 1958) for the remainder made on the 130-125°F. instrument.

The frequency distribution of assessments relative to the thermal sensation scale is shown in Fig. 2. The bias towards a feeling of warmth will be noticed and the relative absence of extremes, to the extent that, apart from a single vote of eight, only seven of the nine possible assessments were utilized. These features are believed to be due to the slight preponderance of daytime readings and the gap in the observations from September, 1949, to April, 1950, on the one hand, and to the fact that the indoor climate was to some extent under the control of the subject on the other.

The main features of the basic data may be seen by inspecting the correlation tables of the thermal assessment with the air temperature (Table 2), with the water vapour pressure (Table 3), with the air velocity (normalized by extracting the square root) (Table 4) and the correlation table of the air temperature with the square root of the air velocity (Table 5). Owing to a serious post-war shortage of electric fans the indoor air velocities were unusually low, fans being absent from all the premises used, with one exception.

Analysis I

The data were fitted to an equation of the form $C = at + bp + cv^{\frac{1}{2}} + d$, where C is the thermal assessment on the scale of Table 1; a, b, c, and d are numerical coefficients to be determined; while t is the Fahrenheit air temperature, p the water vapour pressure in mm. of mercury, and v the air velocity in feet per minute. The method employed was as follows: In order to eliminate as far as possible the effects of personal idiosyncrasies the

TABLE 2

CORRELATION TABLE FOR THERMAL ASSESSMENT AND AIR TEMPERATURE

Air Temperature to nearest °F.	Thermal Assessment									Totals
	0	1	2	3	4	5	6	7	8	
92							2	2		4
91				1				1		2
90					1			3		4
89					4	2		5		11
88				3	4		2	4		13
87			1	1	1	2	18	16		39
86				4	10	10	10	12	1	47
85				6	6	11	16	4		43
84			6	17	11	14	20	3		71
83			4	1	11	11	9			36
82			2	5	12	10	7			36
81			1	2	1	3	4			11
80		2	9	9	9	6	8			43
79		3	10	8	1					22
78		2	7	2						11
Totals	0	7	40	59	71	69	96	50	1	393

TABLE 3

CORRELATION TABLE FOR THERMAL ASSESSMENT AND WATER VAPOUR PRESSURE

Water Vapour Pressure to nearest mm.	Thermal Assessment									Totals
	0	1	2	3	4	5	6	7	8	
30								4		4
29							1	9		10
28				1			4	11		16
27					1		3	5		9
26				5	7	8	14	9		43
25			12	13	19	21	33	5	1	104
24			10	22	21	29	29	4		115
23		2	12	13	18	9	12	3		69
22		5	6	5	5	2				23
Totals	0	7	40	59	71	69	96	50	1	393

TABLE 4

CORRELATION TABLE FOR THERMAL ASSESSMENT AND SQUARE ROOT OF AIR VELOCITY

(Air Velocity)$^{\frac{1}{2}}$ to nearest (ft./min.)$^{\frac{1}{2}}$	Thermal Assessment									Totals
	0	1	2	3	4	5	6	7	8	
1				1	1	3				5
2				1	1		3			5
3			6	2	7	12	15	4	1	47
4		1	17	15	21	26	28	8		116
5			11	8	6	13	15	6		59
6		6	3	11	5	9	6	5		45
7			3	3	5	1	19	8		39
8				6	10		5	8		29
9				3	3	2	2	2		12
10				1	3	1	2	3		10
11				1	3	1	1	3		9
12				3	2	1		2		8
13					2			1		3
14				3	1					4
15										
16					1					1
17										
18										
19				1						1
Totals	0	7	40	59	71	69	96	50	1	393

TABLE 5

CORRELATION TABLE BETWEEN AIR TEMPERATURE AND SQUARE ROOT OF AIR VELOCITY

(Air Velocity)$^{\frac{1}{2}}$ to nearest (ft./min.)$^{\frac{1}{2}}$	Air Temperature to Nearest °F.															Totals
	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	
1	1				1	3										5
2		1	1				1	2								5
3		4	10	1	4	4	10	3	9	2						47
4	3	2	19	3	14	12	25	13	18	7						116
5	2	6	6	4	5	7	11	7	5	4					2	59
6	5	7	4	2	6	2	2	9	3	5						45
7				1	2	2	7	2	4	12	5	2	1			39
8					1	6	6	2	3	5	5	1				29
9			1		1		4	2	2		1				1	12
10							3	2	1	1		2			1	10
11								1		2	1	3	1	1		9
12		1	1		1				2	1	1			1		8
13												2	1			3
14			1				2					1				4
15																
16													1			1
17																
18																
19					1											1
Totals	11	22	43	11	36	36	71	43	47	39	13	11	4	2	4	393

thermal assessment was considered to be of the form $C = \bar{C} + (C - \bar{C})$ where $\bar{C}$ was the average thermal assessment obtained by a single observer in a particular batch of observations. It was found that $(C - \bar{C})$ was distributed approximately normally with respect to the sensation scale, whereas the distribution of $\bar{C}$ had no recognizable form (Figs. 3a and 3b). The variation of $(C - \bar{C})$ is to a marked extent related to the variations in temperature, water vapour pressure, and air velocity, but not, of course, to the observer or the place of observation. It measures in fact the average reaction of the observers to changes in the physical climate.

The correlations of $(C - \bar{C})$ with $(t - \bar{t})$, $(p - \bar{p})$, and $(v^{\frac{1}{2}} - \bar{v}^{\frac{1}{2}})$, where $\bar{t}$, $\bar{p}$, and $\bar{v}^{\frac{1}{2}}$ are the average values of t, p, and $v^{\frac{1}{2}}$ for the separate batches of observations, were then examined. The coefficients

TABLE 6

COEFFICIENTS OF CORRELATION BETWEEN THERMAL ASSESSMENT AND PHYSICAL VARIABLES

Variable	Coefficient of Direct Correlation with Thermal Assessment	Coefficient of Partial Correlation (the Other Two Variables being Held Constant) with Thermal Assessment
Temperature	+ 0·57**	+ 0·55**
Vapour pressure	+ 0·40**	+ 0·25**
(Air velocity)$^{\frac{1}{2}}$	+ 0·05	− 0·22**

**Denotes significance at the 0·1 % level.

of direct correlation of the thermal assessment with the physical variables appear in the second column of Table 6 and show the strong connexion with temperature and water vapour pressure, but only an insignificant correlation with air movement. The partial correlation coefficients, the remaining two variables being held constant in each case, are

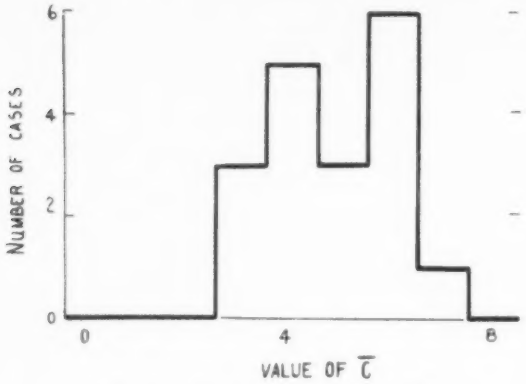


FIG. 3a.—Distribution of 18 values of $\bar{C}$.

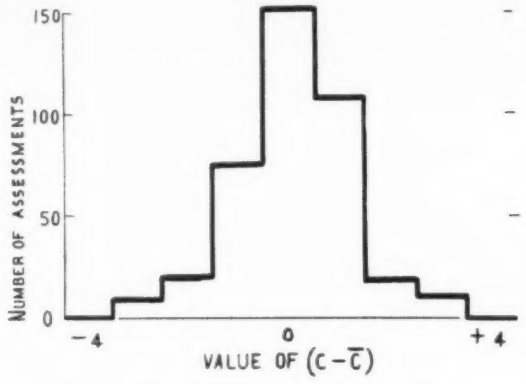


Fig. 3b.—Distribution of 393 values of $(C-\bar{C})$.

shown in the third column of Table 6 and indicate very highly significant correlation in all three cases unaffected by the correlation between temperature and air velocity which is noticeable, for instance, in Table 5.

The regression coefficients were next estimated within the batches of observations using an analysis of covariance, *i.e.*, in effect analysing the variation of $(C - \bar{C})$ on $(t - \bar{t})$, $(p - \bar{p})$ and $(v^{\frac{1}{2}} - \bar{v}^{\frac{1}{2}})$. The estimates which were obtained are given in Table 7.

TABLE 7

REGRESSION COEFFICIENTS OF THERMAL ASSESSMENT ON PHYSICAL VARIABLES

Variable	Regression Coefficient of Thermal Assessment on the Variable	Standard Error	t-value
Temperature	+ 0·256	0·020	12·56
Vapour pressure	+ 0·218	0·042	5·22
(Air velocity)$^{\frac{1}{2}}$	− 0·103	0·025	4·13

The values of $\bar{t}$, $\bar{p}$, and $\bar{v}^{\frac{1}{2}}$ affect that of the blank term in the regression equation, which ranged from − 22·74 to − 19·40 with an unweighted average of − 21·19.

An additional term in $v^{\frac{1}{2}} \cdot t$ was considered for inclusion in the regression equation, but the correlation of this product with the thermal assessment was found to be due to the correlation with $v^{\frac{1}{2}}$ and t separately, and a comparison of mean squares showed that such a term could safely be ignored.

The regression equation is therefore

$$C = 0{\cdot}256\,t + 0{\cdot}218\,p - 0{\cdot}103\,v^{\frac{1}{2}} - 21{\cdot}19 = a{\cdot}t + b{\cdot}p + c{\cdot}v^{\frac{1}{2}} + d \qquad (i)$$

Now an equation of this type is rather informative. It gives the equivalence (Houghten and Yagloglou, 1923) between water vapour pressure and temperature in their effects on thermal sensation, *viz.*, an increase of 1 mm. of mercury in the water vapour pressure is equivalent to an increase of temperature of $b/a = 0{\cdot}85^\circ$ F. Similarly an increase of 1 (foot per minute)$^{\frac{1}{2}}$ in the square root of the air velocity is equivalent to a decrease in the air temperature of $-c/a = 0{\cdot}40^\circ$ F.

Consequently the equation implies, and would enable one to construct, a climatic scale combining the three physical variables in proportion to their effects on thermal sensation. The scale might take any convenient form and, for instance, it might be defined somewhat on the lines of "effective temperature" (Yaglou, 1949), as the temperature of still, saturated air which produces the same overall thermal sensation. If we accept this definition, and suppose that over a sufficient range for the present purpose the saturated water vapour pressure may be represented by the expression

$$p_{sat} = e + f{\cdot}t$$

we may write

$$C = a{\cdot}\theta + b\,(e + f{\cdot}\theta) + d \qquad (ii)$$

$$= (a + bf)\,\theta + (be + d) \qquad (iii)$$

where θ is the value of the climatic index, and the conditions $v = 0$ and $p = p_{sat}$ have been inserted. Solving for θ we have

$$\theta = \frac{C - (be + d)}{(a + bf)} \qquad (iv)$$

We may eliminate C between equations (i) and (iv), obtaining

$$\theta = \frac{a}{a + bf} \cdot t + \frac{b}{a + bf} \cdot p + \frac{c}{a + bf} \cdot v^{\frac{1}{2}} - \frac{be}{a + bf}$$

$$= 0{\cdot}574\,t + 0{\cdot}488\,p - 0{\cdot}231\,v^{\frac{1}{2}} + 21{\cdot}23 \qquad (v)$$

in the present case, where $p_{sat} = -43{\cdot}46 + 0{\cdot}873\,t$.

The index θ, as defined by equation (v), might be expected to be especially suitable as a measure of climate under the experimental conditions which have been described, and in particular to be superior to the air temperature in this respect. This expectation is confirmed by an examination of the analyses of C, which is a linear function of θ so that the significance tests give the same results for the two

TABLE 8

ANALYSIS OF VARIANCE

Source of Variation	Sums of Squares	D.F.	Mean Squares
Residual variability of C when temperature alone is considered	321·8	374	—
Residual variability of C when vapour pressure and air velocity are also considered	276·7	372	0·74
Improvement in second analysis	45·1	2	22·54

variables. The residual variance of C is noticeably reduced if, after the effect of temperature has been removed, the effects of vapour pressure and air velocity are subsequently allowed for (Table 8). Fisher's z test (Fisher, 1954) shows the improvement to be highly significant.

The reduced residual variability presumably contains contributions from variations in clothing and in thermal idiosyncrasy, and also from errors in measurement and it is not to be expected that any consideration of climatic factors will suffice to reduce it to a very low value.

The improvement which has been achieved is not only statistically significant, it is a very useful one in comparison with the improvements previously obtained. For instance, the widely used effective temperature scale failed to give any improvement on temperature when tested by Bedford (1936), by means of the correlation coefficient. The coefficient between the sensation of coolness and the dry-bulb air temperature was $-0{\cdot}48 \pm 0{\cdot}010$ and that between coolness and the effective temperature was precisely the same. Ho (1952) found, with Singapore data, that the correlation coefficient between the sensation of warmth and the dry-bulb air temperature was $+0{\cdot}52$ and that between warmth and the effective temperature was $+0{\cdot}55$; while the writer found closely similar values to those of Ho, the standard errors of $\pm 0{\cdot}035$ and $\pm 0{\cdot}033$, and the result of the Fisher z test, showing the improvement to be insignificant.

In view of this satisfactory property it is proposed to make use of θ as defined in equation (v) as a new climatic index, and to name it the Singapore index. The correlation table between the thermal assessment and the value of the Singapore index calculated from the observed values of the physical variables t, p, and $v^{\frac{1}{2}}$ follows (Table 9). The coefficient of correlation is $+0{\cdot}65 \pm 0{\cdot}027$, and the improvement on Table 2 is self evident.

The multiple regression equation gives further information which in effect enables one to locate thermal sensation levels on the new climatic scale. The regression of C on θ, for instance, is represented by the equation $C = (a + bf)\,\theta + (be + d) = 0{\cdot}447\,\theta - 30{\cdot}68$, which indicates that the average thermal assessment will be neutral, *i.e.*, $C = 4$, at $\theta = 77{\cdot}6°$ F. However, a more profitable alternative is available.

Analysis II

Following Chrenko (1953a, 1953b, 1955) and Bedford (1954), it is clear that a thermal sensation scale may, with convenience and some logical advantage, be treated not as a numerical scale but as one involving degrees of approach to a quantal response of thermal discomfort. In this sense votes on the scale in Table 1 would be considered to lie in one of two categories. The first category would indicate the absence of discomfort due to warmth, and would include votes 0 (excessively cold) to 5 (comfortably warm); while the second category would indicate the presence of warmth discomfort and include votes 6 (warm) to 8 (excessively hot). The incidence of the discomfort response would be appropriately analysed by the probit method (Finney, 1947).

The incidence of discomfort due to cold could in

TABLE 9

CORRELATION TABLE OF THERMAL ASSESSMENT WITH SINGAPORE INDEX

Singapore Index to nearest °F.	Thermal Assessment									Totals
	0	1	2	3	4	5	6	7	8	
88								2		2
87										
86							1			1
85				1			1	3		5
84								9		9
83						2	6	14		22
82				5	4	9	21	12	1	52
81			1	11	22	18	24	6		82
80			11	10	15	21	22	3		82
79			2	6	13	13	14	1		49
78			10	9	7	5	7			38
77		2	9	9	9	1				30
76		4	5	6	1					16
75		1	2	2						5
Totals	0	7	40	59	71	69	96	50	1	393

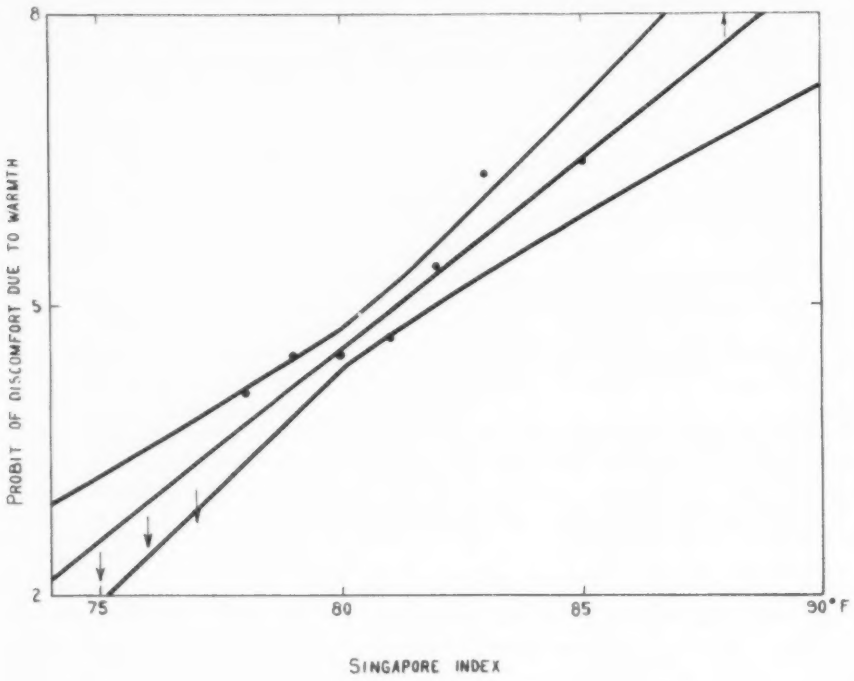
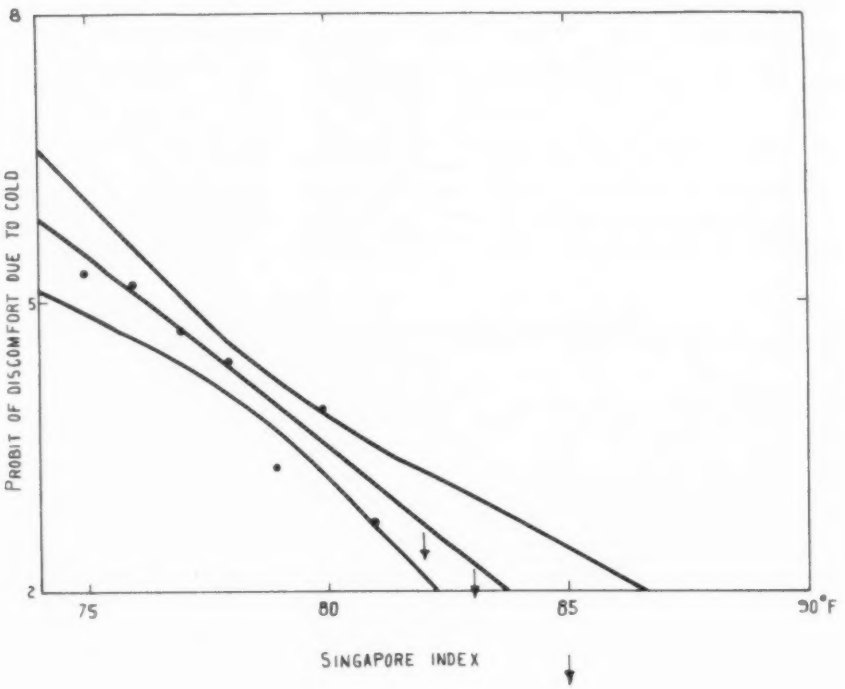


FIG. 4.—Probit regression line, with 95% fiducial band, for the incidence of discomfort due to warmth relative to the value of the Singapore index.

FIG. 5.—Probit regression line, with 95% fiducial band, for the incidence of discomfort due to cold relative to the Singapore index.



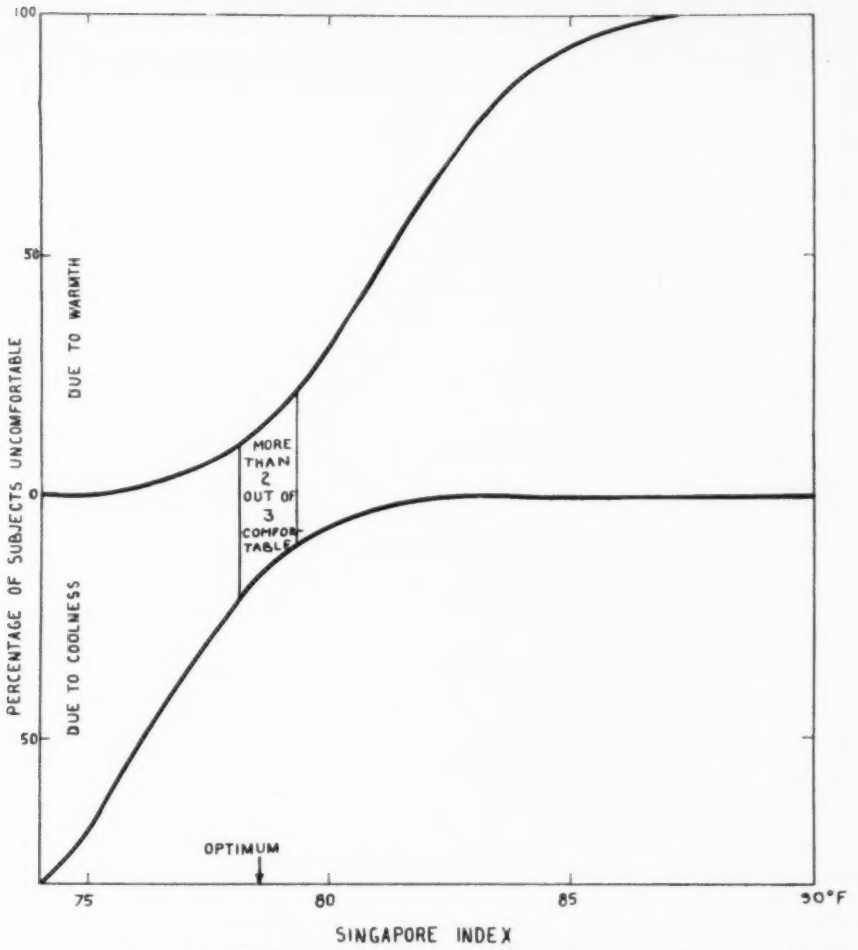


FIG. 6.—The percentage incidence of discomfort due to warmth and cold separately, relative to the Singapore index. The optimum value of the index is marked.

its turn be treated similarly, votes 0 to 2 (cool) being taken to indicate the presence of discomfort due to cold, and votes 3 (comfortably cool) to 8 its absence.

TABLE 10

PROBIT REGRESSION OF WARMTH DISCOMFORT ON SINGAPORE INDEX

Slope of the probit regression line	$0{\cdot}39 \pm 0{\cdot}05$ °F.$^{-1}$
χ^2	13·5
Degrees of freedom	9
Median value of the Singapore index	$81{\cdot}2 \pm 0{\cdot}25$ °F.

TABLE 11

PROBIT REGRESSION OF DISCOMFORT DUE TO COLD ON SINGAPORE INDEX

Slope of the probit regression line	$-0{\cdot}40 \pm 0{\cdot}06$ °F.$^{-1}$
χ^2	11·0
Degrees of freedom	8
Median value of the Singapore index	$76{\cdot}2 \pm 0{\cdot}5$ °F.

This procedure has been adopted, and the probit regression lines have been determined for the incidence of discomfort due to warmth and cold separately, relative to the Singapore index. Data for the incidence of discomfort due to warmth are given in Table 10 and the probit regression line and its 95% fiducial band are illustrated in Fig. 4. Similar data for the response of discomfort due to cold are given in Table 11 and Fig. 5.

Disregarding the sign, the values of the slope are not significantly different. They indicate a similar variability in the population in its response to heat and to cold. The values of χ^2 indicate the presence of a small amount of heterogeneity, which is taken into account in estimating precision.

In order to determine the total incidence of thermal discomfort due to both causes the calculated

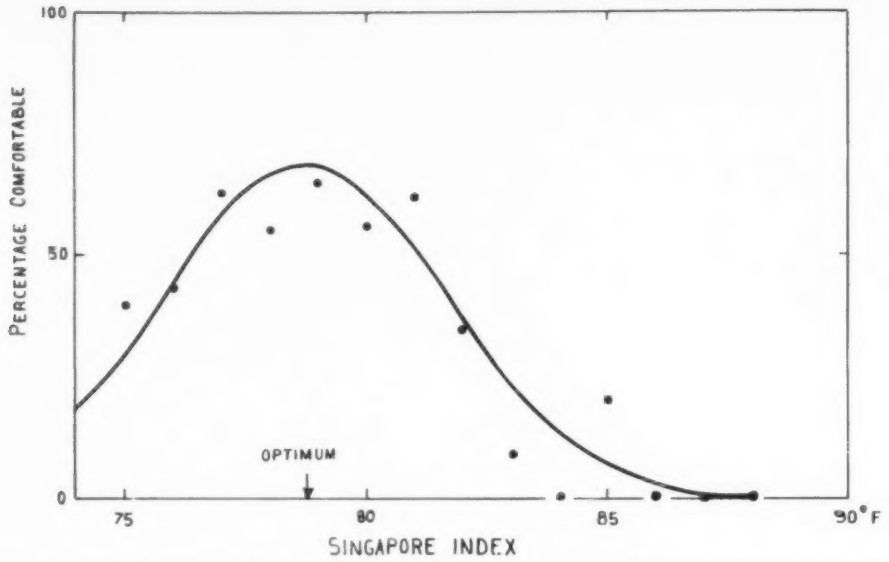


FIG. 7.—The total percentage of subjects feeling no thermal discomfort, relative to the Singapore index. The empirical percentages have been plotted as a check.

probits were converted to percentages (Fig. 6) and added. Subtracting the total from 100 the resulting comfort graph is shown in Fig. 7, where the empirical percentages of subjects casting votes 3 to 5 (indicating the absence of any thermal discomfort) have been plotted for verification.

The Climatic Optimum

From the graph in Fig. 7 we see that the maximum percentage of subjects who are comfortable at any value of the Singapore index is 68% at 78·7° F. The precision of the estimate of the optimum climate is indicated by the fiducial limits in Figs. 3 and 4, giving 95% limits of about ±1·5°F. and ±15% respectively*. For smallish deviations from the optimum value of θ the reduction in the percentage of subjects comfortable is 3 $(\Delta\ \theta)^2$.

As may be seen the comfort graph, not unexpectedly, differs in shape from those obtained in cooler climates. The optimum naturally occurs at a markedly higher temperature, but also the peak is sharper and very much lower. The latter properties could be explained in terms of the lightness of clothing which is appropriate in low latitudes.

For any given value of the Singapore index, including the optimum value, there is a range of interconnected values of the air temperature, the humidity, and the air velocity. From equation (v) we have, for the water vapour pressure at the climatic optimum

$$p = \left[e + \frac{\theta\ \text{opt}\ (a + bf)}{b}\right] - at/b - cv^{\frac{1}{2}}/b$$
$$= 117{\cdot}6 - 1{\cdot}175\ t + 0{\cdot}47v^{\frac{1}{2}} \quad \text{(vi)}$$

The given climate can be defined on the t, p plane by a set of parallel lines representing various constant values of the air velocity, and the optimum

*In connexion with the estimate of precision it is desirable to consider briefly the way in which the separate batches of data are distributed in Table 9, since there is an assumption implicit in probit analysis that subjects, *e.g.*, insects in a toxicity test, are used only once; or at least that the information from each subject has an equal weight, and has been derived under the same uniformly applied range of test conditions. The latter stipulation especially would be difficult to satisfy under field conditions, and in the present case neither was precisely satisfied. The facts are as follows:

The average number of assessments per observer was 28·1, and 10 out of the 14 observers made between 25 and 31 assessments. Of the remainder, three made 15 or 16 assessments; and one made 55 assessments in one building, and 15 or 16 in each of two others, giving a total of 86 assessments. The last-mentioned observer experienced a full range of climatic variation and appeared to have no marked idiosyncrasy; but the others were subjected to a more restricted range of variation, especially the three who made daytime observations only.

Turning to the probit regression lines, there is good evidence that their slope is correct, since they are members of a family of parallel lines derivable from Table 9. The median value of the Singapore index for the occurrence of discomfort due to warmth is based, in effect, on the observations of seven or eight individuals and so is unlikely to be seriously affected by the idiosyncrasies of any of them The median for discomfort due to cold is, however, less well based, as it comes from only four observers. The value does receive some outside support from symmetry and from the height of the maximum, and is at least uncontradicted by the empirical percentages. In the opinion of the writer it is of value at least temporarily.

The usable information previously quoted, *viz.*, the optimum value of the Singapore index, the maximum percentage of subjects comfortable, and the reduction in the percentage due to a departure from the optimum, are supported by the empirical data and it does not seem probable that the stated precision, contingent on the assumption mentioned, is a serious overestimate.

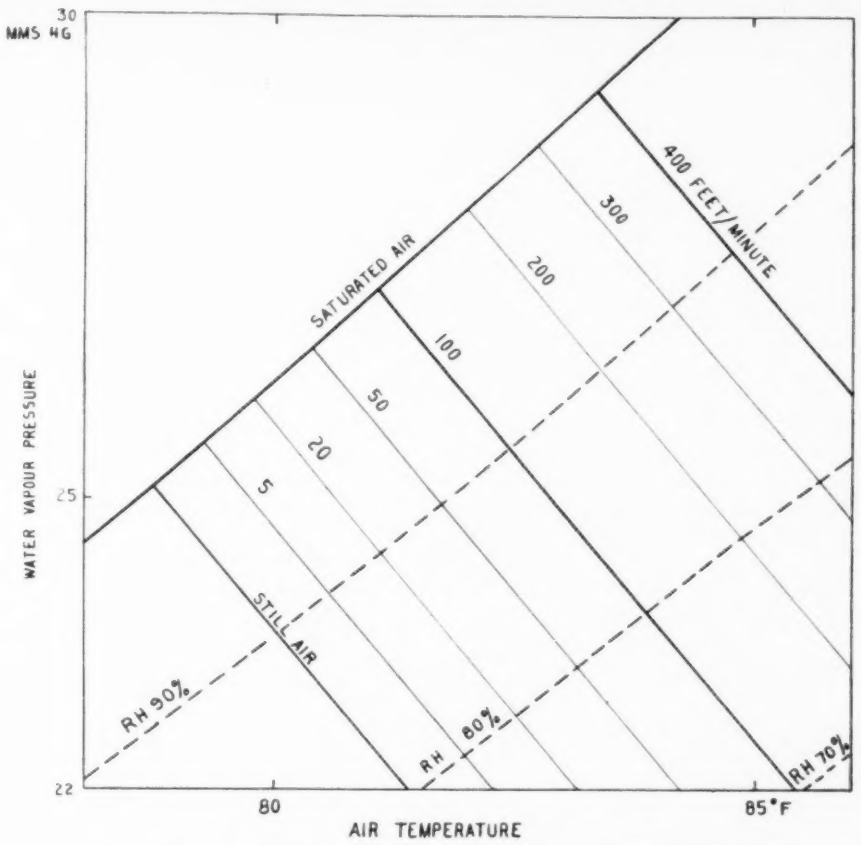


FIG. 8.—The group of climates corresponding to the optimum value of the Singapore index.

climate is depicted in this way in Fig. 7. Within the optimum climate, if it is assumed that the most desirable values of the air velocity and the relative humidity are 40 feet per minute and 70% respectively, the air temperature most desired by the subjects tested would have been about 84° F. These ideal conditions were not observed.

Rapid Determination of the Singapore Index

The Singapore index may, as an alternative to equation (v), be defined in terms of the dry- and wet-bulb temperatures, respectively denoted by t and t_w, in which case we have

$$\theta = \frac{(a - b\,AH)t}{a + bf} + \frac{b(AH + f)\,t_w}{a + bf} - \frac{cv^{\frac{1}{2}}}{a + bf}$$

where H is the height of the mercury barometer and A is the wet-bulb factor, so that when we substitute the previous values for a, b, c, f, and H and the value 0·00343 for A we have, in British units,

$$\theta = 0{\cdot}447\,t + 0{\cdot}553\,t_w - 0{\cdot}231\,v^{\frac{1}{2}} \qquad \text{(vii)}$$

or, with sufficient accuracy for most purposes,

$$\theta = \tfrac{1}{2}\,(t + t_w) - \tfrac{1}{4}v^{\frac{1}{2}} \qquad \text{(viii)}$$

These equations, and especially the latter, are obviously more convenient than (v) and should be used whenever possible. The error in equation (viii) is $0{\cdot}053\,(t - t_w) - 0{\cdot}019\,v^{\frac{1}{2}}$ which is almost always positive, has a value of about 0·2°F. in an ordinary case, and is not more than 0·4°F. in the most unfavourable case from the present climatic range.

Comfort Chart for Singapore

The comfort graph in Fig. 7 may be combined with the relevant section of a psychrometric chart to give a convenient means of assessing a warm, humid climate from the point of view of thermal comfort.

For still air we have

$$\begin{aligned} p &= -\,at/b + (a + bf)\,\theta/b + e \\ &= -\,1{\cdot}175t + 2{\cdot}047\,\theta - 43{\cdot}46 \end{aligned} \qquad \text{(ix)}$$

For successive integral values of θ we obtain on the t, p chart (Fig. 9) a set of equally spaced parallel

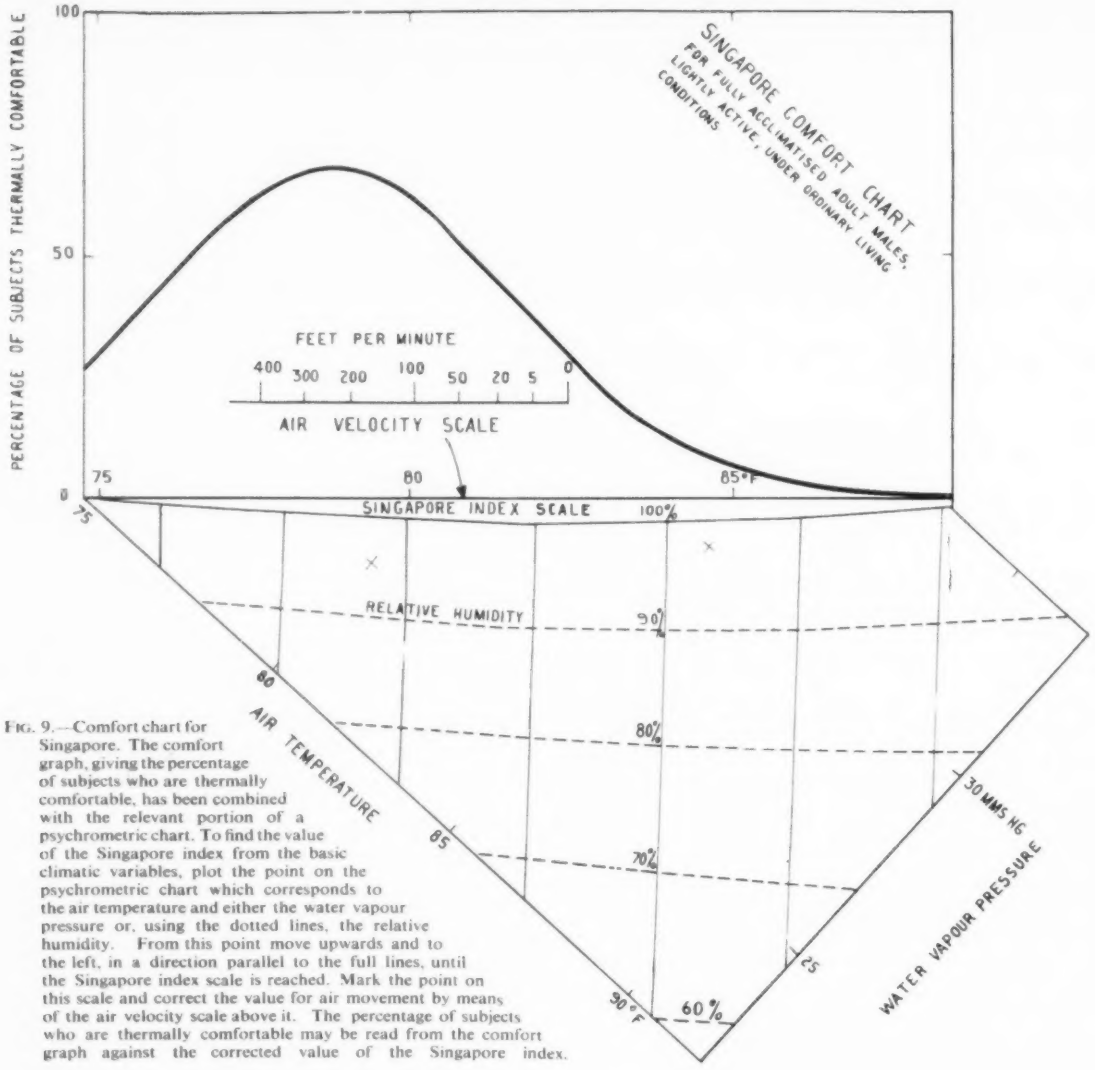


FIG. 9.—Comfort chart for Singapore. The comfort graph, giving the percentage of subjects who are thermally comfortable, has been combined with the relevant portion of a psychrometric chart. To find the value of the Singapore index from the basic climatic variables, plot the point on the psychrometric chart which corresponds to the air temperature and either the water vapour pressure or, using the dotted lines, the relative humidity. From this point move upwards and to the left, in a direction parallel to the full lines, until the Singapore index scale is reached. Mark the point on this scale and correct the value for air movement by means of the air velocity scale above it. The percentage of subjects who are thermally comfortable may be read from the comfort graph against the corrected value of the Singapore index.

lines of slope − 1·175 mm. Hg/°F. and spacing 1·75° F. along the t axis. The intersections with the saturated vapour pressure line occur at the selected values of θ. Lines for even values of θ from 76 to 88° F. inclusive are shown in Fig. 9, and a scale of θ is marked above the saturated vapour line.

The value of θ now needs to be corrected for the effect of air movement, and this may be done by means of the adjacent scale of air velocity. With the final value of θ so obtained, the percentage of subjects who are thermally comfortable may be read from the attached comfort graph. The chart may be used (1) to assign a value of the Singapore index to a given climate, and (2) to determine the modifications necessary to achieve the optimum.

The Effect of Climatic Spread

Even under the optimum climatic conditions nearly a third of the subjects investigated were thermally uncomfortable. However, this high proportion of discomfort might be expected to be avoidable under ordinary living conditions since the climate in a room is rarely uniform, and the occupants are usually free to move to the places they consider most comfortable. In this way the natural spread of climate round the optimum makes it possible to satisfy individual requirements, and is beneficial.

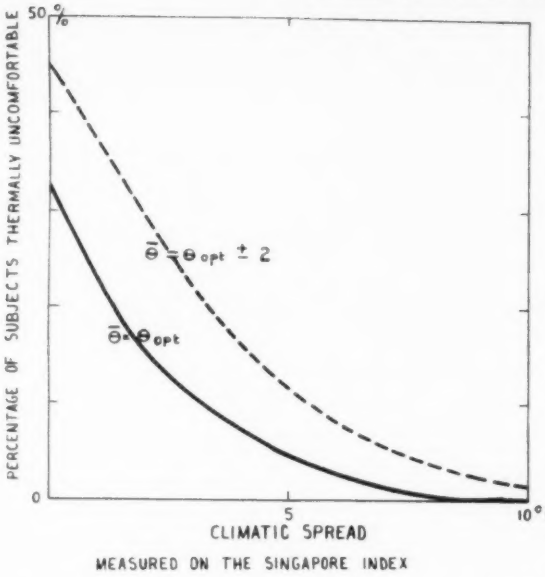


FIG. 10.—The relation between the spread of climate on either side of the optimum, measured on the Singapore index, and the percentage of subjects who are thermally uncomfortable. In the case of the full-line graph the climate is spread equally on each side of the optimum, and in that of the dotted graph it is centred 2 °F., on the Singapore index, away from the optimum.

It is on the other hand undesirable that the spread of climate should be very large in a room that is at all fully occupied, since an excessive spread would clearly either reduce the used area of the room or cause discomfort in a proportion of the occupants. It is therefore advisable to try to estimate the extent of climatic spread that may be expected to be beneficial. This may be done by the use of Fig. 6, as follows: Consider a point on the upper graph at $\theta = \theta_c$. Evidently by reducing the value of θ_c, and so moving the point to the left, it is possible to reduce the percentage of subjects who are warm to a completely negligible figure; at the same time, however, an increasing percentage of subjects, indicated by the lower graph, will feel cool. The latter can become comfortable again if there are available places to which they can move, where $\theta = \theta_w$, a value of the index, to be read from the lower graph, at which the percentage of subjects who feel cool is negligible. The total percentage of subjects who are thermally uncomfortable can obviously be reduced as required by adjusting the limits θ_c and θ_w. This total will be equal to the sum of the ordinates to the respective graphs at the above-mentioned values of the index.

The relation between the width of the climatic spread, *i.e.* $(\theta_w - \theta_c) = \Delta\theta$, and the total percentage of subjects who are uncomfortable, is depicted in Fig. 10. In the case of the full-line graph the spread is centred on the climatic optimum so that $\bar{\theta} = \frac{1}{2}(\theta_w + \theta_c) = \theta_{opt}$, and in that of the dotted graph it is centred 2° F. away, *i.e.*, $\bar{\theta} = \theta_{opt} \pm 2°$ F. From an inspection of the graph it can be seen that a spread of about 4 or 5° F. in the Singapore index can be highly beneficial, since it may remove thermal discomfort from all but about 5% of subjects; but on the other hand twice as much spread would be pointless, and might be detrimental. The allocation of floor space to both extremes of climate need not be large, *e.g.*, not more than about 25% of the total available.

Conclusions

The warm and humid Singapore indoor climate has been described in relation to the overall thermal sensations of fully acclimatized subjects, and a Singapore index for climate has been defined by the equations

$$\begin{aligned}\theta &= 0{\cdot}574t + 0{\cdot}488p - 0{\cdot}231v^{\frac{1}{2}} + 21{\cdot}23\\ &= 0{\cdot}447t + 0{\cdot}553t_w - 0{\cdot}231v^{\frac{1}{2}}\\ &\doteqdot \tfrac{1}{2}(t + t_w) - \tfrac{1}{4}v^{\frac{1}{2}}\end{aligned}$$

where θ is the value of the index in degrees Fahrenheit, and t and t_w are the dry- and wet-bulb temperatures on the same scale, p is the water vapour pressure in millimetres of mercury, and v the air velocity in feet per minute. The index has a coefficient of correlation + 0·65 with thermal sensation and is believed to be a significant improvement on any index at present available for climates of this kind.

The incidence of thermal discomfort due to warmth amongst fully acclimatized adult males, lightly active under ordinary living conditions was:

Singapore index	74	76	78	80	82	84	86	88° F.
Percentage of subjects uncomfortable due to warmth	0	2	12	32	63	86	97	100

while the incidence of thermal discomfort due to cold under the same conditions was:

Singapore index	74	76	78	80	82	84° F.
Percentage of subjects uncomfortable due to cold	81	53	23	6	1	0

The optimum value of the Singapore index was 78·7 $\pm \frac{3}{4}$° F., when 68 $\pm$ 8% of the subjects were thermally comfortable. For smallish deviations $\Delta\theta$ from the optimum the reduction in the percentage of subjects comfortable was 3 $(\Delta\theta)^2$.

Within the optimum any two of the above-

mentioned physical variables may vary independently, in accordance with the equation

$$p = 117{\cdot}6 - 1{\cdot}175t + 0{\cdot}47v\sqrt{}.$$

If it is assumed that the ideal air velocity indoors is 40 feet per minute and the ideal relative humidity 70%, then the air temperature at which discomfort would be a minimum is 84° F., under the conditions described.

A spread of climate in a single room of about 2° F. on the Singapore index on each side of the optimum makes it possible to reduce the percentage of subjects who are thermally uncomfortable to 5.

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LATE CONSEQUENCES OF THE NEUROLOGICAL FORMS OF DECOMPRESSION SICKNESS

BY

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(RECEIVED FOR PUBLICATION OCTOBER, 1958)

Various neurological forms of decompression sickness are classified and an inquiry two and a half to five and a half years after the acute illness is reported.

One hundred subjects with decompression sickness of the central nervous system were examined.

In more than half of the cases the clinical picture was that of chronic encephalomyelopathy, vegetative neurosis, or psychosomatic symptoms. Symptoms were found in three-quarters of the cases, and objective signs in the same proportion. Fourteen patients were unable to work two and a half to five and a half years after the acute illness, and only 13 of 100 patients were reported to be reasonably well.

The best and only adequate treatment for decompression sickness is recompression. After recompression the prognosis for recovery is increasingly poor the longer time passes, and after the first six weeks there is no hope of a perfect recovery.

The pathological changes in the spinal cord caused by decompression trauma in divers and caisson workers have already been described, as also have cases of damage to the brain, but the characteristics of the neurological form of decompression sickness are not as yet generally known. The future of these patients is also uncertain because histories of individual cases are not sufficient to make any general prognosis.

During the building of the metro in Budapest, all cases of decompression sickness in which the patients were unable to work for three days or more were referred to us. It was therefore possible for us to make a systematic study of caisson sickness and to analyse the results of our investigation (Rózsahegyi and Soós, 1956), and in a period of from two and a half to five and a half years after the acute illness, I have followed up 100 patients to see if I could evaluate the prognosis of decompression sickness affecting the central nervous system.

Each manifestation of decompression sickness of the central nervous system is in effect a multifocal lesion, but it is possible to differentiate between four types, namely, (1) the syndrome of multiple focal injuries of the whole of the central nervous system; (2) the syndrome in which there are multiple lesions in the cerebrum and the upper brain-stem; (3) the syndrome of injury to the medulla, pons, and cerebellum; and (4) the syndrome exhibiting spinal lesions. The essential features of these various forms will be described briefly here; for greater detail our monograph should be consulted (Rózsahegyi and Soós, 1956).

Neurological Forms

(1) **Multiple Focal Injuries of the Whole Central Nervous System.**—The illness begins acutely with a general collapse, central hypoxaemia, or with signs of "pseudo-Ménière's disease", by which we mean dizziness caused by a lesion of the bulbar vestibular nuclei, that is, of central origin as opposed to the Ménière syndrome caused by a lesion of the labyrinth of peripheral origin. The onset is swift. In slight cases, when there is no loss of consciousness, the signs of paraplegia and autonomic disturbances are unequivocal (sweating, dizziness, pallor). Complete recovery after recompression is rare, and in most cases residual signs in the form of a secondary disseminated encephalomyelopathy can be observed. In one-third of the cases a vegetative neurosis and in another third pathological, hysterical changes of the personality are seen as late complications.

(2) **Multiple Lesions in Cerebrum and Upper Brain-stem.**—Regional cortical aeropathy is a not very frequent event in caisson workers but that of the

upper brain-stem, diencephalon, and ponto-mesencephalon is often found. It generally begins without premonitory symptoms with sudden collapse and unconsciousness; if there are warning symptoms, these consist of blurring of vision (retinal aeropathy), but not systemic dizziness, headache, and serious vegetative symptoms. Focal symptoms remain. A psychosomatic syndrome is in more than half of these cases a frequent late sequel. The acute illness is often followed by a vegetative neurosis.

(3) **Injury to the Medulla Oblongata, Pons, and Cerebellum.**—There are cases in which an isolated lesion of the bulbar vestibular nuclei may be observed. In those cases, the after-effects are noted as an instability of the vestibular mechanism. In other cases of this group there are, mostly in addition to the vestibular defect, signs of damage to cranial nerve nuclei and the long nerve tracts. Both kinds of lesion often appear in the form of central collapse with dizziness, which cannot be differentiated in the acute phase from the Ménière syndrome of peripheral origin. We have described this as the pseudo-Ménière syndrome. Later it is possible to differentiate between the two forms. Cases of "peripheral" Ménière syndrome recover without lasting damage or else the typical symptoms of the chronic permanent Ménière syndrome persist, mostly with serious damage to the cochlear apparatus. Cases of the pseudo-Ménière syndrome are left with dizziness but without any damage to hearing. The otoneurological state is normal in these cases or there is evidence of a central lesion. A frequent consequence is a vegetative neurosis with a tendency to fainting.

A lesion in the cerebellum is not frequent but is serious.

Cases of massive air embolism of the vital bulbar centres may end fatally.

(4) **Spinal Lesions.**—It is necessary to distinguish those cases with a lesion below the tenth thoracic segment. After a prodromal paraesthesia an acute atonic paraplegia follows, and, in spite of recompression, there is retention of urine for several days. A very frequent consequence is complete or partial impotence. The paralysis of the lower limbs is followed by slight spasticity after a shorter or longer period. Corresponding to the position of the lesion there are residual sensory disturbances.

Tetraplegia is characteristic of multifocal lesions of the spinal cord, and develops with frightening speed although the patient remains conscious. The result is disseminated myelopathy, or, if the brain is also affected, encephalomyelopathy. Also there are cases of primary chronic myelopathy or encephalomyelopathy in which the development of decompression trauma is insidious. No acute illness after decompression injury has been noted. The diagnosis is made in these cases during a routine examination or for another illness and is based on focal symptoms.

In addition to primary and secondary myelopathy and encephalomyelopathy there are, as late consequences of the neurological appearance of decompression sickness, certain clinical signs, namely, a vegetative neurosis and a pathological change of personality or pseudo-neurasthenia or hysteria.

The vegetative neurosis is mostly associated with focal symptoms of the bulb and pons. It is seen after the acute damage to the upper brain-stem, cerebral, or multifocal cerebrospinal lesions, but never after an isolated lesion of the spinal cord. For this reason we are of the opinion that it is not of psychological origin but is a consequence of an organic lesion of the autonomic centres around the third and fourth cerebral ventricle and the aqueduct of the mid-brain. The most frequent complaints are anorexia, headache, disorders of sleep, lassitude. The most frequent symptoms are the signs of derangement of the whole of the autonomic nervous system (tremor, dermographismus, exaggerated reflexes, dilated pupils, often a slight exophthalmos).

The psychosomatic syndrome can be seen in about a third of the cases of neurological decompression sickness. These cases all have a lesion of the brain-stem ganglia and of the diencephalon, and the syndrome never follows an isolated lesion of the spinal cord. The changes in personality are of particular importance. Men who were quiet before injury become extremely irritable and uncontrolled. Pathological drunkenness and alcohol intolerance are also frequent.

The neurological enquiry was made after the acute decompression sickness as follows:—

In 3 cases after 2½ years
In 3 cases after 3 years
In 3 cases after 3½ years
In 18 cases after 4 years
In 34 cases after 4½ years
In 36 cases after 5 years
In 3 cases after 5½ years

The ages at the time of the investigation were as follows:—

Between 20 and 29 years of age .. 5 subjects
Between 30 and 39 years of age .. 58 subjects
Between 40 and 49 years of age .. 32 subjects
Between 50 and 56 years of age .. 5 subjects

The clinical picture in the different appearances of the acute illness is shown in Table 1. No definite defect remained in about one half of the cases (41%); the fewest cases without any residual defects were those of the multifocal cerebrospinal lesions (24·39%). This too was the only group of patients left with two (two cases) or three (one case) definite symptoms.

TABLE 1

RELATION OF CHRONIC CLINICAL PICTURES TO FORM OF ACUTE ILLNESS

Acute Syndrome	Patients (No.)	Chronic Clinical Picture									
						Psychosomatic Syndrome					
		Secondary Myelopathy	Secondary Encephalo-myelopathy	Primary Encephalo-myelopathy	Vegetative Neurosis	Pseudo Neurasthenia	Hysteria	Pathological Change of Personality	Double	Triple	None
Multiple focal injuries of central nervous system	41	1 (2·4%)	13 (31·7%)	—	2 (4·9%)	8 (+2) (19·5%)	2 (+1) (4·9%)	2 (+1) (4·9%)	2 (4·9%)	1 (2·4%)	10 (24·4%)
Multiple lesions of cerebrum and upper brain-stem	8	—	—	—	3 (37·5%)	—	—	1 (12·5%)	—	—	4 (50·0%)
Injury to medulla, pons, and cerebellum	39	—	6 (15·4%)	—	6 (15·4%)	3 (7·7%)	—	2 (5·1%)	—	—	22 (56·4%)
Spinal lesions	10	4 (40·0%)	1 (10·0%)	—	—	—	—	—	—	—	5 (50·0%)
Primary chronic forms	2	—	—	1	—	1	—	—	—	—	—
	100	5	20	1	11	12 (+2)	2 (+1)	5 (+1)	2	1	41

TABLE 2

SYMPTOMS

Acute Syndrome	Patients (No.)	Headache	Dizziness	Weakness	Irritability	Disturbance of Sleep	Alcohol Intolerance and Pathological Drunkenness	Disturbance of Potency	Buzzing in Ear	Disturbance of Hearing	Forgetfulness	No Symptoms
Multiple focal injuries of central nervous system	41	19 (46·2%)	25 (60·8%)	8 (19·5%)	21 (51·1%)	19 (46·2%)	6 (14·6%)	16 (38·9%)	5 (12·2%)	8 (19·5%)	7 (17·0%)	7 (17·0%)
Multiple lesions of cerebrum and upper brain-stem	8	3 (37·5%)	2 (25·0%)	1 (12·5%)	2 (25·0%)	—	2 (25·0%)	—	—	—	—	4 (50·0%)
Injury to medulla, pons, and cerebellum	39	20 (51·3%)	19 (48·7%)	4 (10·3%)	15 (38·5%)	10 (24·3%)	7 (18·0%)	8 (20·5%)	3 (7·3%)	3 (7·3%)	3 (7·3%)	9 (20·4%)
Spinal lesions	10	3 (30·0%)	2 (20·0%)	—	2 (20·0%)	2 (20·0%)	1 (10·0%)	3 (30·0%)	—	—	1 (10·0%)	6 (60·0%)
Primary chronic forms	2	1	1	1	—	—	—	1	—	—	—	—
	100	46	49	14	40	31	16	28	8	11	11	26

A vegetative neurosis was the most frequent final consequence after the acute illness of a lesion of the upper brain-stem: three-quarters of these cases were left with sequelae.

The different forms of the psychosomatic syndrome persisted after several years only in such cases in which the upper segments of the central nervous system were affected, but never after the lesion of the spinal cord. This syndrome was also most common in the first of our groups, that exhibiting multiple focal lesions of the whole of the central nervous system.

For a long time after lesions of the spinal cord neither a vegetative neurosis nor a psychosomatic syndrome could be observed.

Table 2 summarizes symptoms. There were no symptoms several years after the illness in more than half of the cases of the fourth group (spinal lesions), in half of the second group (lesions of the cerebrum and upper brain-stem), but in the first and third groups only one-fifth of the cases were without symptoms. The most frequent were dizziness (49%), headache (46%), and increased irritability (40%).

The dizziness was continuous only in a few cases, but in most it was brought on by change of position or it appeared in paroxysms. Many patients reported dizziness while travelling. Headaches were seldom continuous; most patients complained about frequently returning headache. Sleep was often disturbed: most patients complained of insomnia, but in other cases of sleepiness, and in a few cases of both disturbances with inverse sleep rhythm.

Sexual potency was disturbed in 28 cases. In seven of the 16 cases of the first group the impotence

TABLE 3
SIGNS

Acute Syndrome	Patients (No.)	Tendon Reflexes: Upper Limb	Tendon Reflexes: Lower Limb	Absent Plantar Reflex	Absent Cremaster Reflex	Absent Abdominal Wall Reflex	Pathological Reflexes	Nystagmus	Deviation of Tongue	Past Pointing	Sinking of the Arms	Dysdiadochokinesis	Dysmetria of Lower Limbs	Romberg Test	Walking with Closed Eyes Deviation	No Signs
Multiple focal injuries of central nervous system	41	1 (2·4%)	10 (24·4%)	24 (58·4%)	8 (19·5%)	11 (26·8%)	2 (4·9%)	5 (12·2%)	4 (9·7%)	12 (29·2%)	2 (4·9%)	7 (17·0%)	13 (31·6%)	7 (17·0%)	12 (29·2%)	8 (19·5%
Multiple lesions of cerebrum and upper brain-stem	8	—	1 (12·5%)	4 (50·0%)	1 (12·5%)	1 (12·5%)	—	3 (37·5%)	—	2 (25·0%)	1 (12·5%)	2 (25·0%)	—	1 (12·5%)	3 (37·5%)	2 (25·0%
Injury to medulla, pons, and cerebellum	39	1 (2·6%)	2 (5·1%)	10 (25·6%)	6 (15·4%)	7 (18·0%)	2 (5·1%)	6 (15·4%)	2 (5·1%)	5 (12·8%)	2 (5·1%)	2 (5·1%)	5 (12·8%)	6 (15·4%)	9 (23·1%)	15 (38·5%
Spinal lesion	10	1 (10·0%)	5 (50·0%)	7 (70·0%)	3 (30·0%)	5 (50·0%)	2 (20·0%)	1 (10·0%)	—	—	—	—	1 (10·0%)	—	—	3 (30·0%
Primary chronic forms	2	—	—	—	1	—	—	2	1	1	1	1	1	1	1	—
	100	3	18	45	19	24	6	17	7	20	6	12	20	15	25	28

was complete, in nine cases partial (with unsatisfactory erection or diminished sexual desire). The eight cases of the third group were all partial, the three cases of the fourth group all complete.

Other complaints were only sporadic.

Among the objective findings (Table 3) the most frequent was the absence of the plantar reflex, not so frequent the absence of the abdominal reflex. Unsteadiness in walking with closed eyes was observed in every fourth case, faulty postural sense of the lower extremities and past pointing in every fifth case. The tendon reflexes showed abnormalities in the lower extremities in 18, and in three cases in the upper extremities being increased, absent, or different on the two sides. Pathological reflexes were seen only in six cases examined a long time after the acute phase. Other neurological signs were sporadic.

Most symptoms and most objective findings were in the first group, namely, in the syndrome of multifocal aeropathy of the whole of the central nervous system as was expected. Even the fact of multiple foci does not make it possible to relate the single complaints and symptoms to particular structures. This is possible only in the more differentiated forms. Headache, dizziness, increased irritability, and disturbances of hearing and of equilibrium seem to be related to lesions of the cerebellum, pons, and the bulb; weakness, alcohol intolerance, nystagmus, and disturbances of motion to those of the cerebrum and upper brain-stem. Disturbances of potency, absence of skin reflexes (plantar, cremaster, abdominal) and difference or absence of tendon reflexes and pathological reflexes (Babinsky, Oppenheim) are related to lesions of the spinal cord.

The course of the neurological form of decompression sickness is not invariable. There are cases in which the recompression in the medical lock was fully effective and they showed no defect immediately after the decompression or later.

M.I. had decompression sickness at the age of 26. After decompression he experienced irritation and numbness in the buttocks and thighs. He was at once given recompression in the medical lock at a pressure of 2·9 atmospheres and symptoms ceased, and four and a half years later he has no signs or symptoms.

V.K. had caisson sickness at the age of 26. He had been working at a pressure of 1·5 atmospheres. He felt dizzy and his feet were numb in the caisson during decompression. During the recompression, which was carried out immediately after a hot shower and at a pressure of 2·9 atmospheres, the symptoms disappeared, and after eight hours he left the medical lock without any symptoms. Four years later he has no signs or symptoms.

In other cases the symptoms disappeared in the medical lock during the recompression and they did not reappear immediately afterwards, but later either the same or new symptoms were experienced and with them corresponding objective signs.

M.G., aged 39, on July 14, 1955, had decompression sickness. He had been working for three and a quarter hours at a pressure of 1·4 atmospheres. During the decompression the right arm began to twitch and later the right arm and lower limb became numb and insensible and painful. The pressure in the medical lock was immediately raised again but he became dizzy and pale and his face was paralysed; he was unable to speak and lost consciousness. In the medical lock he regained consciousness and all symptoms disappeared at a pressure of 2·2 atmospheres. Seven hours later he left the medical lock without symptoms. The next day he had headache, but no other symptoms and the neurological examination yielded no pathological signs. At examination on August 29 he also had no complaints and no neurological symptoms. On November 1 he complained of headache and dizziness, but had no objective symptoms except

anaesthesia of the vestibular nerve and a hypoaesthesia of the cochlear nerve. He complained further about headache, weakness, and uncertainty in walking, without other objective findings. Not before December 14, 1955, however, did he show neurological symptoms. Then he had a dysdiadochokinesia of the left arm and absent abdominal reflexes. On March 22, 1956, he reported increased irritability, impatience, and impotence. Neurological and otoneurological findings were unchanged till the examination in February, 1958. Then he reported numbness and dull pains in the feet and from time to time he had fever. He still had dysdiadochokinesia of the left arm, absent abdominal reflexes, and an absent right patellar reflex.

In the following case, over a period of several months, chronic encephalomyelopathy and a pathological change of personality developed, and seems to be fixed.

St. F., aged 46, on December 30, 1955, had worked for six hours at a pressure of 1·6 atmospheres and three hours after ceasing work he had decompression sickness. First he had a feeling of numbness in the sacral region and in the thighs, later he became anaesthetic from the hips downwards. By recompression up to 2·8 atmospheres he lost these symptoms and left the medical lock seven hours later apparently well. The next day he again felt numbness in the feet and reported the same symptoms at examination on January 3, 1956. The objective findings were a very marked diminution of reflexes of the lower limbs, hypoaesthesia on the right side from D_6, on the left from D_{10} downwards, absent cremasteric reflexes and absent right plantar reflex. There was a pronounced ataxia of the right lower limb. The next day he had disturbances of micturition, so that he had to be admitted to hospital. He was discharged improved after 24 days. On January 26 the right Achilles jerk was absent and also the right plantar reflex and there was ataxia and adynamia of the right lower limb. In the middle of February the patellar and tendon of Achilles reflexes disappeared. On March 6 he reported improvement, and his only complaint was a stabbing pain in the spine. Only the plantar reflex was positive. At the end of March he was without complaints with unchanged objective findings.

Two years later, on February 11, 1958, he complained of weakness of the feet, discomfort in passing water, temporary incontinence, and complete impotence. He had dysmetria of the lower limbs (right worse than the left), absence of the patellar and tendon of Achilles reflexes and of the cremasteric reflexes and diminished plantar reflexes.

This is a case of the slow evolution of damage to the spinal cord, which leaves behind a definite defect with impotence, temporary incontinence, and weakness of the lower limbs.

In some cases, perhaps due to faults in the technique of recompression, the symptoms did not disappear in the medical lock but persisted or got worse. In the acute phase it is remarkable that the subjective complaints and the objective signs show considerable variation. They diminish or disappear for hours or even days then return, perhaps aggravated. This variability in the severity of signs and symptoms may continue for several weeks or months. Convalescence in the slight cases lasts some days, in the majority of the cases three to six months. After a year there is generally no hope of recovery, but in some exceptional cases recovery is possible even after several years.

M.A., aged 22 years, on November 10, 1953, had worked for three and a half hours under pressure and then, after a break of 20 minutes, for a further four hours. About 45 minutes after the second working period he developed a headache and in about an hour felt ill, lost consciousness, and needed recompression. After seven and a half hours' treatment he felt weak and giddy though the pressure had been raised to 2·8 atmospheres. He had a multifocal air embolism of the central nervous system with a lesion of the cerebellum. After recompression he still had paroxysms of dizziness and could not travel without becoming giddy. He was impotent. He showed a positive Romberg test, ataxia of the trunk, nystagmus to the left, past pointing, ataxia of the inferior extremities, and exaggerated tendon reflexes. His symptoms got worse, together with disturbances of the autonomic nervous system and he became weak.

In November, 1954, the dizziness was still constant but less severe. At this time there was deviation of the tongue to the right, dysdiadochokinesia of the right arm, and the nystagmus was now observed in both directions; paresis of the right abducens was found also. Walking with closed eyes could not even be attempted because the patient fell at once.

In November, 1955, there was some change in his symptoms. The paroxysms were less frequent, but he was feeling a continuous sensation of a pull to the right. He slept 14 to 16 hours a day. The ataxia of the trunk was not now noted, but nystagmus, dysdiadochokinesia, past pointing, and a positive Romberg test persisted. The patellar reflex was on both sides exaggerated. He was unfit for work.

In August, 1956, he had sufficiently improved to be able to perform an administrative job, and in October, 1956, he dared to begin to study law. He was still prone to dizziness, but not so much as before; with closed eyes he felt unsafe. Any slight physical effort also provoked weakness.

In May, 1958, he had only the sensation of a slight pull to the right; he did not have paroxysms of dizziness any longer, and felt unsafe only during travel. The sleepiness and the impotence stopped. He felt well and his only complaint was that he could not ride a cycle. The tongue still showed deviation to the right, there was a nystagmus in both directions (to the left slight, to the right marked), and past pointing with both hands, the right more pronounced than the left. Dysdiadochokinesia was not present. The Romberg test was positive, but not so pronounced as before. Walking with closed eyes was now possible, but with a strong deviation to the right.

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In the following case, over a period of several months, chronic encephalomyelopathy and a pathological change of personality developed, and seems to be fixed.

St. F., aged 46, on December 30, 1955, had worked for six hours at a pressure of 1·6 atmospheres and three hours after ceasing work he had decompression sickness. First he had a feeling of numbness in the sacral region and in the thighs, later he became anaesthetic from the hips downwards. By recompression up to 2·8 atmospheres he lost these symptoms and left the medical lock seven hours later apparently well. The next day he again felt numbness in the feet and reported the same symptoms at examination on January 3, 1956. The objective findings were a very marked diminution of reflexes of the lower limbs, hypoaesthesia on the right side from D_6, on the left from D_{10} downwards, absent cremasteric reflexes and absent right plantar reflex. There was a pronounced ataxia of the right lower limb. The next day he had disturbances of micturition, so that he had to be admitted to hospital. He was discharged improved after 24 days. On January 26 the right Achilles jerk was absent and also the right plantar reflex and there was ataxia and adynamia of the right lower limb. In the middle of February the patellar and tendon of Achilles reflexes disappeared. On March 6 he reported improvement, and his only complaint was a stabbing pain in the spine. Only the plantar reflex was positive. At the end of March he was without complaints with unchanged objective findings.

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M.A., aged 22 years, on November 10, 1953, had worked for three and a half hours under pressure and then, after a break of 20 minutes, for a further four hours. About 45 minutes after the second working period he developed a headache and in about an hour felt ill, lost consciousness, and needed recompression. After seven and a half hours' treatment he felt weak and giddy though the pressure had been raised to 2·8 atmospheres. He had a multifocal air embolism of the central nervous system with a lesion of the cerebellum. After recompression he still had paroxysms of dizziness and could not travel without becoming giddy. He was impotent. He showed a positive Romberg test, ataxia of the trunk, nystagmus to the left, past pointing, ataxia of the inferior extremities, and exaggerated tendon reflexes. His symptoms got worse, together with disturbances of the autonomic nervous system and he became weak.

In November, 1954, the dizziness was still constant but less severe. At this time there was deviation of the tongue to the right, dysdiadochokinesia of the right arm, and the nystagmus was now observed in both directions; paresis of the right abducens was found also. Walking with closed eyes could not even be attempted because the patient fell at once.

In November, 1955, there was some change in his symptoms. The paroxysms were less frequent, but he was feeling a continuous sensation of a pull to the right. He slept 14 to 16 hours a day. The ataxia of the trunk was not now noted, but nystagmus, dysdiadochokinesia, past pointing, and a positive Romberg test persisted. The patellar reflex was on both sides exaggerated. He was unfit for work.

In August, 1956, he had sufficiently improved to be able to perform an administrative job, and in October, 1956, he dared to begin to study law. He was still prone to dizziness, but not so much as before; with closed eyes he felt unsafe. Any slight physical effort also provoked weakness.

In May, 1958, he had only the sensation of a slight pull to the right; he did not have paroxysms of dizziness any longer, and felt unsafe only during travel. The sleepiness and the impotence stopped. He felt well and his only complaint was that he could not ride a cycle. The tongue still showed deviation to the right, there was a nystagmus in both directions (to the left slight, to the right marked), and past pointing with both hands, the right more pronounced than the left. Dysdiadochokinesia was not present. The Romberg test was positive, but not so pronounced as before. Walking with closed eyes was now possible, but with a strong deviation to the right.

TABLE 3
SIGNS

Acute Syndrome	Patients (No.)	Tendon Reflexes: Upper Limb	Tendon Reflexes: Lower Limb	Absent Plantar Reflex	Absent Cremaster Reflex	Absent Abdominal Wall Reflex	Pathological Reflexes	Nystagmus	Deviation of Tongue	Past Pointing	Sinking of the Arms	Dysdiadochokinesis	Dysmetria of Lower Limbs	Romberg Test	Walking with Closed Eyes Deviation	No Signs
Multiple focal injuries of central nervous system	41	1 (2·4%)	10 (24·4%)	24 (58·4%)	8 (19·5%)	11 (26·8%)	2 (4·9%)	5 (12·2%)	4 (9·7%)	12 (29·2%)	2 (4·9%)	7 (17·0%)	13 (31·6%)	7 (17·0%)	12 (29·2%)	8 (19·5%)
Multiple lesions of cerebrum and upper brain-stem	8	—	1 (12·5%)	4 (50·0%)	1 (12·5%)	1 (12·5%)	—	3 (37·5%)	—	2 (25·0%)	1 (12·5%)	2 (25·0%)	—	1 (12·5%)	3 (37·5%)	2 (25·0%
Injury to medulla, pons, and cerebellum	39	1 (2·6%)	2 (5·1%)	10 (25·6%)	6 (15·4%)	7 (18·0%)	2 (5·1%)	6 (15·4%)	2 (5·1%)	5 (12·8%)	2 (5·1%)	2 (5·1%)	5 (12·8%)	6 (15·4%)	9 (23·1%)	15 (38·5%
Spinal lesion	10	1 (10·0%)	5 (50·0%)	7 (70·0%)	3 (30·0%)	5 (50·0%)	2 (20·0%)	1 (10·0%)					1 (10·0%)			3 (30·0%
Primary chronic forms	2	—	—	—	1	—	—	2	1	1	1	1	1	1	1	—
	100	3	18	45	19	24	6	17	7	20	6	12	20	15	25	28

was complete, in nine cases partial (with unsatisfactory erection or diminished sexual desire). The eight cases of the third group were all partial, the three cases of the fourth group all complete.

Other complaints were only sporadic.

Among the objective findings (Table 3) the most frequent was the absence of the plantar reflex, not so frequent the absence of the abdominal reflex. Unsteadiness in walking with closed eyes was observed in every fourth case, faulty postural sense of the lower extremities and past pointing in every fifth case. The tendon reflexes showed abnormalities in the lower extremities in 18, and in three cases in the upper extremities being increased, absent, or different on the two sides. Pathological reflexes were seen only in six cases examined a long time after the acute phase. Other neurological signs were sporadic.

Most symptoms and most objective findings were in the first group, namely, in the syndrome of multifocal aeropathy of the whole of the central nervous system as was expected. Even the fact of multiple foci does not make it possible to relate the single complaints and symptoms to particular structures. This is possible only in the more differentiated forms. Headache, dizziness, increased irritability, and disturbances of hearing and of equilibrium seem to be related to lesions of the cerebellum, pons, and the bulb; weakness, alcohol intolerance, nystagmus, and disturbances of motion to those of the cerebrum and upper brain-stem. Disturbances of potency, absence of skin reflexes (plantar, cremaster, abdominal) and difference or absence of tendon reflexes and pathological reflexes (Babinsky, Oppenheim) are related to lesions of the spinal cord.

The course of the neurological form of decompression sickness is not invariable. There are cases in which the recompression in the medical lock was fully effective and they showed no defect immediately after the decompression or later.

M.I. had decompression sickness at the age of 26. After decompression he experienced irritation and numbness in the buttocks and thighs. He was at once given recompression in the medical lock at a pressure of 2·9 atmospheres and symptoms ceased, and four and a half years later he has no signs or symptoms.

V.K. had caisson sickness at the age of 26. He had been working at a pressure of 1·5 atmospheres. He felt dizzy and his feet were numb in the caisson during decompression. During the recompression, which was carried out immediately after a hot shower and at a pressure of 2·9 atmospheres, the symptoms disappeared, and after eight hours he left the medical lock without any symptoms. Four years later he has no signs or symptoms.

In other cases the symptoms disappeared in the medical lock during the recompression and they did not reappear immediately afterwards, but later either the same or new symptoms were experienced and with them corresponding objective signs.

M.G., aged 39, on July 14, 1955, had decompression sickness. He had been working for three and a quarter hours at a pressure of 1·4 atmospheres. During the decompression the right arm began to twitch and later the right arm and lower limb became numb and insensible and painful. The pressure in the medical lock was immediately raised again but he became dizzy and pale and his face was paralysed; he was unable to speak and lost consciousness. In the medical lock he regained consciousness and all symptoms disappeared at a pressure of 2·2 atmospheres. Seven hours later he left the medical lock without symptoms. The next day he had headache, but no other symptoms and the neurological examination yielded no pathological signs. At examination on August 29 he also had no complaints and no neurological symptoms. On November 1 he complained of headache and dizziness, but had no objective symptoms except

anaesthesia of the vestibular nerve and a hypoaesthesia of the cochlear nerve. He complained further about headache, weakness, and uncertainty in walking, without other objective findings. Not before December 14, 1955, however, did he show neurological symptoms. Then he had a dysdiadochokinesia of the left arm and absent abdominal reflexes. On March 22, 1956, he reported increased irritability, impatience, and impotence. Neurological and otoneurological findings were unchanged till the examination in February, 1958. Then he reported numbness and dull pains in the feet and from time to time he had fever. He still had dysdiadochokinesia of the left arm, absent abdominal reflexes, and an absent right patellar reflex.

In the following case, over a period of several months, chronic encephalomyelopathy and a pathological change of personality developed, and seems to be fixed.

St. F., aged 46, on December 30, 1955, had worked for six hours at a pressure of 1·6 atmospheres and three hours after ceasing work he had decompression sickness. First he had a feeling of numbness in the sacral region and in the thighs, later he became anaesthetic from the hips downwards. By recompression up to 2·8 atmospheres he lost these symptoms and left the medical lock seven hours later apparently well. The next day he again felt numbness in the feet and reported the same symptoms at examination on January 3, 1956. The objective findings were a very marked diminution of reflexes of the lower limbs, hypoaesthesia on the right side from D_6, on the left from D_{10} downwards, absent cremasteric reflexes and absent right plantar reflex. There was a pronounced ataxia of the right lower limb. The next day he had disturbances of micturition, so that he had to be admitted to hospital. He was discharged improved after 24 days. On January 26 the right Achilles jerk was absent and also the right plantar reflex and there was ataxia and adynamia of the right lower limb. In the middle of February the patellar and tendon of Achilles reflexes disappeared. On March 6 he reported improvement, and his only complaint was a stabbing pain in the spine. Only the plantar reflex was positive. At the end of March he was without complaints with unchanged objective findings.

Two years later, on February 11, 1958, he complained of weakness of the feet, discomfort in passing water, temporary incontinence, and complete impotence. He had dysmetria of the lower limbs (right worse than the left), absence of the patellar and tendon of Achilles reflexes and of the cremasteric reflexes and diminished plantar reflexes.

This is a case of the slow evolution of damage to the spinal cord, which leaves behind a definite defect with impotence, temporary incontinence, and weakness of the lower limbs.

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The tendon and skin reflexes were normal except the plantar reflex, which was absent. There was poor postural sense of the right lower limb, on the left there was no abnormality.

In this case three years were necessary to obtain a significant improvement and only four years after the acute illness could the patient be regarded as well, though with residual defects.

E.K., aged 38, on January 30, 1954, had a multifocal aeropathy of the central nervous system. He had worked for six hours at a pressure of 1·6 atmospheres and one hour after stopping work he had pain in the right arm and leg. Later he developed paraesthesiae, formication, and a feeling of weakness. He was at once recompressed and raised to a pressure of 2·7 atmospheres. His symptoms ceased and he left the air chamber after seven hours with only slight pain in the limbs. He had the sensation of palsy and of paraesthesia in the feet and pains in the limbs of the left side. At the acute phase he showed a sinking tendency in the left arm, nystagmus to the left, and deviation to the left on walking with closed eyes. The otoneurological examination showed a serious lesion of both branches of the eighth cranial nerve on both sides. This lesion healed in 12 weeks, but the symptoms did not become less grave and dizziness and nausea were added, particularly, if he travelled or even if he only looked at moving vehicles. He complained of impotence. In June, 1954, the complaints were unchanged but in the left arm there was weakness and a significant dysdiadochokinesia, absence of the patellar reflexes, and ataxia of the right lower limb. The symptoms lasted, with fluctuations, a whole year; there were disturbances of the autonomic nervous system and headache. The objective findings were also unchanged and not before March, 1955, was there a slight improvement. At this time he was able to travel without dizziness and nausea and to try some easy physical work. In July he tried harder work, but he fell repeatedly and lost consciousness; he had paroxysms of dizziness. His potency returned at this time.

At the end of 1956 he began work in a coal-mine. In February, 1957, he had his last paroxysm of dizziness, and at the end of March his potency began once more to decrease. In June, 1957, he had no symptoms, and except for the absence of the right plantar reflex there are no objective findings. Potency returned after injections of yohimbin, strychnine, and tocopherol.

This patient had needed three years to recover from air embolism of the central nervous system though his symptoms at the end of that time were slight.

In the cases which were free from complaints and symptoms two and a half to five and a half years after the acute illness one subject was free immediately, four subjects were free one week later, five two weeks later, two three weeks later, one four weeks later, and one subject was well six weeks later. Those patients who had complaints six weeks after the decompression still have residual symptoms after several years. The outlook for a complete recovery must be evident in the first six weeks.

The tendency to recover after decompression sickness of the central nervous system is good, but in about three-quarters of the cases there remain objective symptoms or signs which prove lasting damage to these tissues. There are only 14 of 100 subjects who show no signs or symptoms more than two years after the acute illness, and if we disregard slight symptoms or signs this number is not even half the cases (36%). Of 100 subjects, there were 14 who, up to the time of this investigation, were not able to work. From this point of view, each case of decompression sickness of the central nervous system is to be regarded as grave and the prognosis as dubious.

The first group has the worst prognosis, and there were only three cases (7·32%) in which no complaints and no objective symptoms were found: in nearly all the cases a definite lesion of the central nervous system remained. The prognosis of lesions of the spinal cord is better: in nearly one-third of the cases recovery is complete. The prognosis of the other groups is between these two.

How may the prognosis of decompression sickness of the central nervous system be ameliorated? First it is essential to take all preventive measures,

TABLE 4

At Time of Epicritic Investigation		After Discharge from Medical Lock		
		Symptoms		
		None	Uncertain	Persistent
	Patients (No.)	28	18	52
No symptoms or signs	14	9 (64·3%) (32·1%)	3 (21·4%) (16·7%)	2 (14·3%) (3·9%)
Slight symptoms and signs	15	5 (33·3%) (17·9%)	4 (26·7%) (26·7%)	6 (40·0%) (11·5%)
Severe symptoms and signs	69	14 (20·3%) (50·0%)	11 (15·9%) (61·1%)	44 (63·8%) (84·6%)

which consist in preventing fluctuations of pressure in the caissons, keeping the climatic environment even, and ensuring conditions of safe decompression. Medical prevention should ensure the selection of fit subjects for caisson work and the elimination of those who exhibit an increased predisposition to decompression sickness. The subject who repeatedly falls sick with the same type of decompression sickness is particularly prone to the neurological form. Moreover, decompression sickness of the central nervous system leaves the patient with an increased predisposition to it and it is not advisable for him to return to caisson work.

The prevention of definite defects of the central nervous system is the correct therapy of every case of decompression sickness, and the only treatment is recompression, the most important part of which is the decompression. It is wise in serious cases to order a prolonged decompression, the American "overnight soak", even if it lasts for 24 hours or more.

The auspices for recovery after decompression are not good. Of those who were free from complaints after decompression in the medical lock, two and a half to five and a half years after the acute illness, more than half were free from complaints but nearly half of the cases had either serious signs or symptoms. In those cases in which the recompression was ineffective and complaints remained after leaving the medical lock, not one in 25 patients was healthy after some years, and in 84·6% of the cases there were serious signs or symptoms (Table 4).

All other treatment is of secondary significance. It is usual to give vasodilators, such as nicotinic acid, papaverine, and, to assist the regeneration of nervous elements, vitamin B.

Nicolas and his colleagues used intravenous injections of procaine in the therapy of acute osteoarthralgy (bends) with good results. We tried this treatment in neurological cases and gained the impression that, if applied early enough, it is useful. We gave 10 ml. of the 1½ to 2% solution slowly intravenously. The cases are too few to form a definite opinion.

Reference

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LUNG CANCER IN COAL-MINERS

BY

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In a study of coal-miners suffering from lung cancer two features of special interest are recorded. The difficulties in diagnosis are illustrated by case reports. The two-year survival rate after surgical removal of the tumour is significantly better in coal-miners than in non-miners. After operation 87% of coal-miners were alive two years later, compared with only 36% of other patients operated upon. It is suggested that the rate of spread of the tumour to the mediastinal structures, lymph glands, and blood vessels is retarded by the effects of pre-existing dust disease in the lungs. This factor explains the good results in a group of patients selected for surgery.

Surprisingly little information is available on the clinical aspects of the association of lung cancer and coal-miners' dust disease. From a study of 78 coal-miners with lung cancer, a good proportion of whom have been operated on, two points for discussion arise: one, the difficulty in reaching the correct diagnosis at a stage when surgical removal of the lung tumour is possible; the other, the high proportion of coal-miners surviving two or more years after resection compared with the proportion of survivors in non-miners. The figures under consideration are small, but this trend seems definite and because survival after operation has, so far as can be ascertained, never been related to this occupation, the results are discussed from the point of view of factors involved in the control of lung cancer by operation.

Since we are associating post-operative survival solely with the occupation of coal-mining, the difficult correlation of the degree of occupational pneumoconiosis with length of survival after operation will not be attempted; nor is it desirable to speculate on results in welders, smiths, foundry-workers, and stonemasons, workers in whom survival has been longer than anticipated. We shall define a coal-miner simply as a person who has worked five years or more underground at the coal-face, not necessarily in the Warwickshire or south Derbyshire mines, where most of the patients were occupied. Possible differences in the properties of dust from different geographical regions have not been considered.

Diagnosis of Lung Cancer in Miners

In a paper on "Silicotic and Tuberculo-silicotic Lesions Simulating Bronchogenic Carcinoma", Kergin (1952) described eight patients with unilateral radiological densities of the type usually seen in lung carcinoma which were, in fact, caused by silicosis or tuberculo-silicosis. He referred to earlier papers by Woodruff and Kelley (1947) and Bradshaw and Chodoff (1939). James (1955) mentioned the difficulty in diagnosing lung cancer in the presence of massive pneumoconiosis and Kilpatrick, Heppleston, and Fletcher (1954), discussing the differential diagnosis of cavitated coalworkers' progressive massive fibrosis, state that a cavitated bronchial carcinoma is probably the most difficult to exclude. When routine methods fail to confirm a diagnosis the cause of difficulty, we find, is either the slowness in growth of certain lung cancers in miners, or the occasional occurrence of a single radiological shadow due to a localized massive fibrotic lesion without any evidence of simple pneumoconiosis. That other radiological evidence of pneumoconiosis may be absent is important and perhaps this feature is not sufficiently widely recognized. Two examples illustrating this will be described, closely resembling the case reported recently by Davis and Snow (1958). These authors believe that a new classification of pneumoconiosis is required to include solitary lesions occurring in lungs which otherwise show only equivocal findings of pneumoconiosis. The facts support the introduction of this amendment. It has also been observed that the course of some of the diseases, commonly confused with carcinoma, may be modified in miners. Familiarity with these points only increases awareness that mistakes may be made without clarifying any particular problem. In diagnosis, observation of the patient's radiological changes over a period is not helpful. So slowly can the tumour progress that one patient

with a proved carcinoma continued at work for seven years after diagnosis. More active steps are required, provided the clinician accepts that even at thoracotomy differentiation between progressive massive fibrosis, tuberculosis, and carcinoma may not be possible. Kergin (1952) has written about this in detail. Case histories of five patients where doubt existed will illustrate these points. Cases 1 and 2 are examples of localized massive fibrosis thought to be tumour. Cases 3 and 4 demonstrate the insidious advance of the tumour when associated with pneumoconiosis, and Case 5 the manner in which pneumoconiosis may obscure the characteristics of another disease.

Case Reports

Case 1.—T.W., aged 60, was a coal-face worker in a Durham hard coal-mine for 20 years. He retired permanently from mining in 1930 and had never had a chest radiograph taken before 1952. His chest was radiographed then because of general malaise. The film is shown (Fig. 1). A diagnosis of carcinoma was made and the right upper lobe removed. Post-operative examination of the lobe showed a cavity 2·5 cm. in diameter filled with jet black, thin fluid. Some collections of dust with little reaction were present, with denser fibrotic areas around the cavity. There was no evidence of carcinoma. The patient has remained well and his chest radiograph six years after operation is shown (Fig. 2). It may be noted that his last exposure to coal dust was 22 years before operation.

Case 2.—W.R., aged 72, had worked for 50 years in the Warwickshire coal-mines. He was referred in September, 1955, because of a shadow in the chest radiograph, which was detected when the patient reported with a history of productive cough. There had been no haemoptysis. The radiological lesion increased and the film in November, 1955, is shown (Fig. 3.) At about this time the patient had a number of small haemoptyses and although bronchoscopy showed no abnormality, a diagnosis of lung carcinoma was made. In view of the patient's age and absence of symptoms, operation was not advised. The shadow increased slowly in size until February, 1956, when the patient had a further haemoptysis while at work and coughed up a large amount of thin, black sputum. The shadow resolved and the patient is now in his 53rd year of mining. His chest radiograph in 1958 is shown (Fig. 4).

Case 3.—R.C., aged 44 years, worked as a Warwickshire coal-miner for 25 years. His first radiograph in 1955 during a routine radiological investigation showed a small nodule in the left mid-zone on a background of simple pneumoconiosis (Fig. 5). During the next three years the nodule increased in size, although the patient was at work and symptomless. He was seen in 1958 with the picture shown in Fig. 6. There was no confirmatory evidence of tumour, but the lesion was regarded as such and the left upper lobe removed, three years after the date of the original radiological abnormality. The pathological report on the left upper lobe reads . . .

"In the posterior segment there is a firm white growth 3 cm. in diameter arising in relation to the segmental bronchus. The remainder of the lobe contains scattered firm pale nodules up to 2 mm. in diameter, but there is no particular concentration of nodules or of more massive fibrosis in the immediate vicinity of the growth. Numerous small anthracotic areas are also present throughout the lobe. The histological appearances of this specimen are complex. The growth is a bronchiolar cell carcinoma and the firm pale nodules are also tumour foci of similar structure to the main growth. There is no indication as to whether they are foci of multicentric

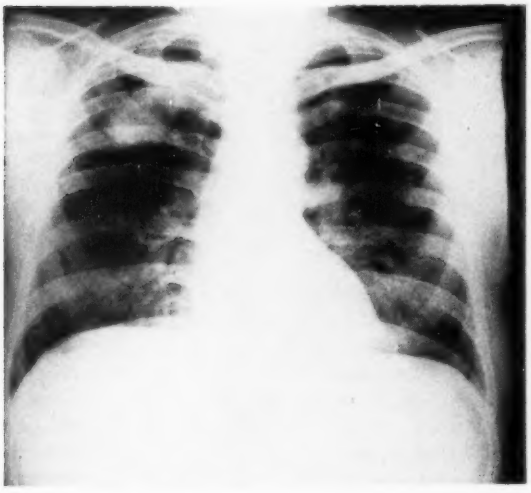

FIG. 1.—Case 1. Mass in right upper lobe thought to be carcinoma. No evidence of pneumoconiosis.

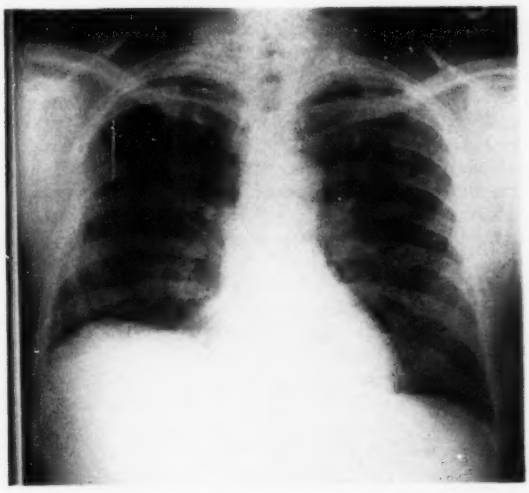

FIG. 2.—Case 1. Six years after resection of right upper lobe.

FIG. 3.—Case 2. Mass in left lower lobe thought to be carcinoma. No evidence of pneumoconiosis.

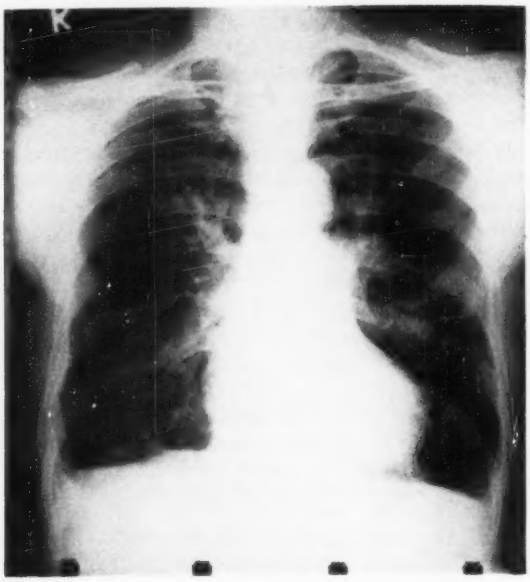

FIG. 4.—Case 2. Present state. Complete resolution of left lower lobe shadow.

tumour or metastases. The small anthracotic areas are foci of simple pneumoconiosis. There are many scattered areas of pneumonitis affecting primary lobules. All combinations of these three lesions are seen in close juxtaposition in different parts of the lobe, but the relationships appear to be accidental. Lymph nodes show anthracosis and metastatic tumour."

The specimen is shown in Fig. 7.

Convalescence from the operation was uneventful and the patient has returned to his previous occupation.

Case 4.—W.J., aged 64, was employed in a South Wales hard coal-mine from 1911 to 1938. He retired in 1938. His first radiograph was in 1947. This film showed simple pneumoconiosis and a disability pension was granted. In 1955 more solid-looking shadows appeared in the right lower zone (Fig. 8). During the next 10 weeks these shadows fluctuated in intensity but never cleared. Bronchoscopy showed a normal bronchial tree. A diagnosis of carcinoma of the right lower lobe was made and operation advised. At operation the whole lung was infiltrated with small hard nodules, with a more confluent mass in the basal segments of the lower lobe. An accurate distinction between carcinoma, tuberculosis, or progressive massive fibrosis, or any combination of these diseases, was not possible. The right lower lobe was removed. Pathological examination showed the lesion to be an epidermoid carcinoma. The hilar glands were anthracotic and fibrosed. At the present time, three years since operation, the patient works as a gardener and has no significant increase in dyspnoea.

Case 5.—H.H., aged 46, a Warwickshire miner for 23 years, had miniature chest films in 1947 and 1954 which were reported as normal. In 1958 he was found to have a circumscribed, rounded shadow in the left lower lobe. The patient was symptom free and a full investigation was not contributory. There seemed no doubt that the lesion was intrapulmonary and as the chest film in 1954 was normal (it was re-perused by Dr. Gordon Evans), a provisional diagnosis of carcinoma was made. At operation the left lung was extensively infiltrated by small hard nodular areas of pneumoconiosis. In the lower lobe a mass about 2·5 cm. in diameter of the same consistency was present. Its characteristics were obscured by the surrounding nodules. A diagnosis by palpation was not possible. The mass was incised; it was thought to be fixed within the lung and a diagnosis of carcinoma was made. A frozen section was considered unnecessary. The lower lobe was removed. Pathological examination revealed the tumour to be a chondromatous hamartoma. In an otherwise normal lung the mobility of this tumour is pathognomonic. Its fixity and loss of definition were due to the pre-existing pneumoconiosis. No ready explanation for the normal appearances in the 1954 chest film is available.

The High Survival Rate in Coal-miners

In the post-operative follow-up of all patients with lung cancer operated on in this hospital, it appeared that patients from agricultural and rural areas generally fared less well than those from industrial districts. A reason for this was sought and it became apparent that the group from the industrial districts included a number of coal-miners. Comparison of the figures for all patients operated on with those for coal-miners is of interest. Of a

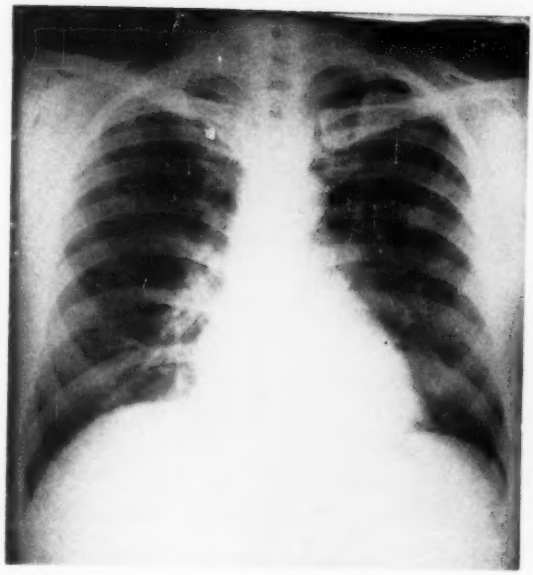

FIG. 5

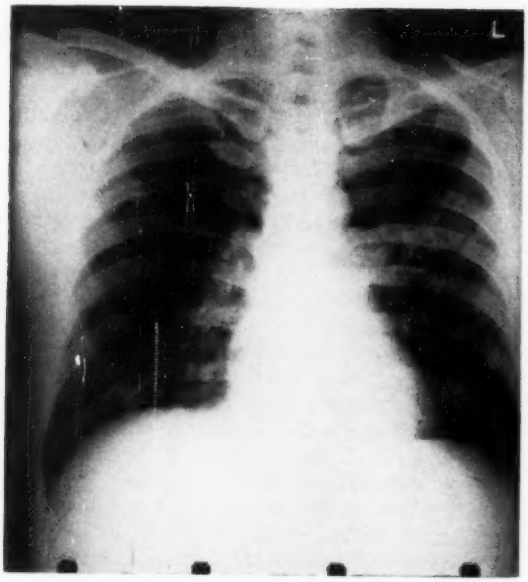

FIG. 6

FIG. 7

FIG. 5.—Case 3. Small left mid-zone shadow on background of simple pneumoconiosis.

FIG. 6.—Case 3. Three years later. Increase in size of left mid-zone shadow.

FIG. 7.—Case 3. Tumour in left upper lobe. The small satellite tumours are not visible.

FIG. 8.—Case 4. Simple pneumoconiosis with increased shadow in the right lower lobe due to carcinoma of the lung.

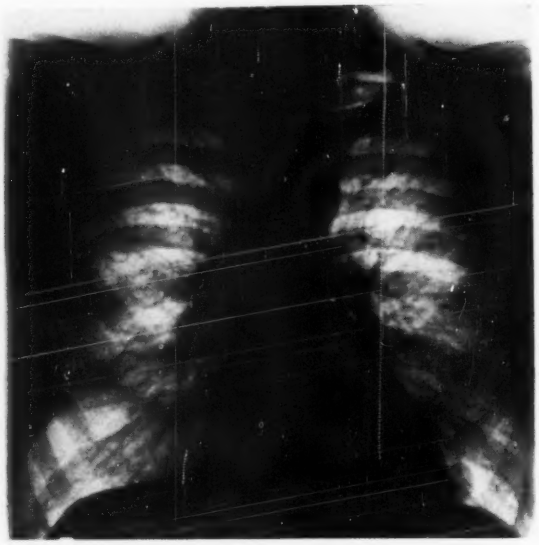

FIG. 9.—Case 5. Circumscribed left lower lobe shadow at time of operation. Thought to be lung carcinoma. Chest radiograph in 1954 known to be normal.

total of 320 patients from all areas operated on, only 36% survived two years or more. Taylor (1954), in an analysis of 512 resections, gives a figure of 34% surviving two years. Bignall and Moon (1955), considering 205 patients operated upon in the years 1950-51, found that 10% died in the first two months after operation and of the survivors of operation, 47% lived two years or more. The 36% survival rate for two or more years in this series may therefore be regarded as an average figure. During the same period with the same criteria of operability, 21 miners have undergone resection and of these only three have died in the first two years; this represents an 86% two-year survival rate, and indicates that in our experience a coal-miner has an appreciably greater chance of survival after operation than the non-miner. To assume that the results of surgery for lung cancer in predominantly coal-mining areas should therefore be correspondingly better than from other areas may be fallacious. The figure may be loaded against better results in the mining areas by increased deaths in the first two years from respiratory insufficiency, or from factors in selection of cases. If, however, the findings in this group of miners are significant, it implies that deaths directly attributable to extension of the tumour should be below average in mining areas. No published figures are available to substantiate this hypothesis.

The results in this study are not to be explained by selection of only the most favourable cases for operation out of all the miners referred for surgery. The two most likely explanations of the results in miners are that the rate of local growth and spread of the tumour are considerably retarded by the effects of prolonged inhalation of coal dust on the lung parenchyma and lymphatics, or that the coal-miner develops a specific and slow-growing type of tumour. James (1955) found no evidence to support the second explanation from microscopic examination of a large number of tumours from coal-miners at necropsy. The former explanation is the more attractive. It may be related to the ill-understood phenomenon that a history of some six months before diagnosis improves the prognosis after resection (Bignall and Moon 1955), or without treatment (Buchberg, Lubliner, and Rubin 1951), compared with the tumour of short history. The numbers resected are too small for any worthwhile analysis of pre-operative length of history, glandular involvement at the time of operation, or other statistical division, but the operative findings confirm Kergin's (1952) description of the characteristic chronic inflammatory type of reaction with lymph glands firmly bound to the vessels and bronchi by very dense fibrous tissue, which is so frequently encountered in coal-miners' lungs. Kergin also draws attention to the fibrosis around the broncho-vascular bundles, the sclerosis of vessels, and the obliteration of lymphatic channels. These gross and microscopic characteristics of the miner's lung offer a possible reason for the retardation in the

local growth and spread of the tumour from the time of its origin. The unfavourable medium which this diffuse fibrosis represents may well depress the vitality of the tumour. Comparison with the changes produced in the lung and its vessels and lymphatics by radiation therapy is a subject for further study. The favourable post-operative result in coal-miners merits further consideration.

I am greatly indebted to Mr. H. V. Wingfield, who operated on Case 1, and to Dr. A. P. Prior and Dr. M. K. Alexander for the pathological reports.

The patients were referred by Dr. E. Calvey, Dr. Gordon Evans, and Dr. J. Sharkey.

I am grateful to Miss D. Beauchamp for her help in collecting information about the patients' follow-up.

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Brit. J. industr. Med., 1959, **16**, 324.

THE ORIGIN OF THE TERM ANTHRACOSIS

INTRODUCED BY

A. MEIKLEJOHN

From the Department of Industrial Health, University of Glasgow

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Dust diseases of the lungs are classified generically as the pneumoconioses. There are several varieties, of which anthracosis was the first to be named specifically. The original article, in which the name anthracosis was coined, is reprinted prefaced by a biographical note on its author.

"When I use a word" said Humpty Dumpty in a rather scornful tone, "it means just what I choose it to mean, neither more nor less". This quotation from "Alice in Wonderland" is not out of place here for it represents an attitude not infrequent in scientific writings. On occasion it is salutary to discover the precise circumstances and facts which led to the introduction of a new term.

In a previous article on the "History of Lung Diseases of Coal-miners in Great Britain" (Meiklejohn, 1951) I recounted the early clinical and pathological observations on black infiltration of the lungs and traced the development of the nomenclature from melanosis to spurious melanosis and finally to anthracosis.

The term "anthracosis", meaning charcoal lung, not black or coal lung, was introduced in 1838 by Dr. Thomas Stratton following attendance at the post-mortem examination on a coal-miner. It occurred to me that the original report would be of wide interest and worthy of reprinting especially as it is my intention later to publish a paper on Zenker's neologism, pneumonokoniosis.

Thomas Stratton was born at Perth, Scotland, in 1816. He lived there until he was 8 years old. The next five years were spent at Dunkeld on the border of the Highlands. From 1829 to 1833 he was in Northumberland and though there is no information on the point, he was probably engaged during this period as an apprentice apothecary. Thereafter he returned to Scotland where he studied medicine at Marischal College, Aberdeen, from 1834 until 1836. This was followed by a year at Edinburgh University. On April 18, 1837, he was admitted as a Licentiate of the Royal College of Surgeons of Edinburgh and on August 1, 1837, he was granted the degree of M.D., Edinburgh. His inaugural thesis was entitled "On Chronic Rheumatism". Then on December 19, 1837, he received his warrant as assistant-surgeon in the Royal Navy, where he spent his whole career. He was promoted Deputy Inspector General of Hospitals and Fleets in 1867. He died on March 16, 1886.

Throughout his life he wrote extensively on a wide variety of medical subjects. However, in our present purpose, it is his avocation which is of greatest interest. He himself records (Stratton, 1870) that in 1831 when he was aged 15 years he "procured a Gaelic Grammar and a Gaelic Dictionary, and some other works, and without any help, in the course of two or three months taught himself the language". This marked the beginning of his interest in languages with particular reference to comparative philology. He published essays—the first in 1840 at the age of 24 years—on the affinity of the Latin, Greek, and Hebrew languages to the Gaelic or Celtic of Scotland (1872). Thomas Stratton was truly a lad o' pairts.

Case of Anthracosis or Black Infiltration of the Whole Lungs

BY

THOMAS STRATTON, M.D.

"The interesting appearance, of which the following case is an instance, was first described by the late Dr. J. C. Gregory in 1831, and since that time several cases have been recorded.

On examining the bodies of elderly persons, we find the lungs always of a dark colour. Sometimes this colour is much deeper in various parts of the lung, which then are as black as charcoal; at other times the whole lungs are uniformly of this charcoal colour.

The first appearance is considered healthy; the second receives the name of melanosis; and the third is what has been called the black lung of coal-miners, and may more shortly be defined *anthracosis* ($\alpha\nu\theta\xi\acute{\alpha}\xi$, charcoal).

On September 29th, 1837, I was invited by Dr. Crawford to witness the inspection of the body of a patient to Dr. Leitch. The history of this patient is as follows.

George Harrison had worked in a coal-mine for 50 years; at his death he was 70; for the last four years he had been an inmate of Tynemouth Workhouse; he had not worked in a coal-mine for some time previously. For some years before his decease, he had been affected with symptoms of chronic *Bronchitis;* the *dyspnoea* was not considerable; his expectoration was small in quantity, and never of a black colour. There was mucous rattle more on the left than the right side of the chest. On percussion, the sound was natural. Latterly he complained much of pain in the right hypochondrium, and had dropsical symptoms in the abdomen and inferior extremities.

Inspection.—Thorax.—On the left side the *pleura pulmonalis* and *pleura costalis* were connected by extensive and firm adhesions. Both lungs uniformly presented a perfectly black appearance externally and when cut into. A portion of them rubbed on the hand left a black stain, which was with some difficulty washed off, and a bit put into water gave it the colour of china-ink. Throughout both lungs were seen and felt hard masses of black matter from the size of a bean downwards. These masses were more numerous in the central parts of either lung, and also were in greater abundance in the central part of the left than of the right lung. In the left lung were several chalky bodies, encased in this black substance. No black substance was found in the bronchial glands. Nor was black matter seen in any other part of the body which was examined.

The heart was natural.

Abdomen.—A considerable quantity of fluid was found within the cavity of the peritoneum. The liver and spleen were much diminished in size. The kidneys were healthy.

Harrison's lung I compared with that of another subject, formerly a man-of-war's man, aged 72. This lung was very much lighter in its colour than Harrison's and did not leave a stain when rubbed on the hand.

It is proper to mention that the coal-miners in this district do not use a lamp attached to the forehead as they do in the west of Scotland.

On the left side there was a greater number of black bodies, more pleural adhesion, and more *bronchitis* than on the right side. It is interesting to observe that these three conditions existed together.

If we suppose the matter of the anthracosis to have been inhaled by the man whilst at work in the mine, and that during the five or six years that he discontinued this kind of work, the lungs were endeavouring slowly to relieve themselves of the foreign matter, then the obstacle to free action of the left lung from pleural adhesion, and the smaller quantity of air which could be admitted along the left bronchial tubes thickened by inflammation, and partially obstructed by mucus, will explain how the anthracosis had become less in the right lung, when these states existed in a much less degree.

If the difference in the quantity of anthracotic matter in the two lungs is not to be explained in this way, then, either, more inhaled black matter has been originally received by the left lung or the function of the elimination of carbon has been less imperfectly performed in the right than in the left lung. With respect to black expectoration in cases of *anthracosis*, I may refer to the instructive paper by Dr. William Thomson, in the London Medico-Chirurgical Transactions for 1836, and of which a short account was given in the last Number of this Journal (January 1838, p. 260).

Dr. Cumin's patient (*Edinb. med. surg. J.*, vol. xlii, p. 324) appears to have been affected with *phthisis pulmonalis*, complicated with anthracosis, as phthisis sometimes is with melanosis. Dr. Laurie's and Dr. Buchanan's cases (ib. pp. 328, 329) prove the existence of anthracosis without the slightest pectoral affection. Dr. Buchanan's case of Lyall seems to have been anthracosis along with peritoneal melanosis.

Melanosis of the lung appears to differ from *anthracosis* in the following particulars. *Melanosis* exists in isolated portions, while *anthracosis* is general over the lung. Of *melanosis*, the local effects are dyspnoea, cough, which is often dry, but sometimes attended with mucous expectoration, and mixed with some puriform sputa, while anthracosis may exist without any chest symptoms whatever. Of *melanosis*, the most constant constitutional symptoms are the gradual diminution of the vital powers, and diminished nutrition followed by hydropic affections, whereas anthracosis often is unexpectedly found to be present when death has occurred from other causes. In *melanosis*, black deposits are generally found in other parts of the body besides the lungs, whilst anthracosis is met with in these alone; and lastly, the matter of melanosis loses its black colour when treated with chlorine (Dr. Henry), whereas the matter of *anthracosis* retains its colour when so treated (Professor Christison)."

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MISCELLANEA

A Laboratory Trial of Some Modern Screening Tests for the Detection of Glucose and Protein in Urine

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From the Medical Centre, the Associated Ethyl Company, Ellesmere Port, Cheshire

(RECEIVED FOR PUBLICATION DECEMBER 17, 1958)

In recent years a number of simple diagnostic tests on urine have been developed which are less time consuming than the procedures previously used. The most important are those for the detection of protein and glucose which will be considered here.

The Ames Company has produced "albustix" and "clinistix" for the testing of urine for protein and glucose respectively. "Albustix" are strips of thick paper impregnated at one end with an indicator, tetrabromphenol blue, and a citrate buffer, approximately *p*H 3. Protein is adsorbed on the outer surface of the strip and produces a colour change in the indicator to green or blue-green caused by the phenomenon known as "protein error". This error occurs when a solution of protein is added to a *p*H indicator and a colour change takes place which is not due to change in *p*H.

The "clinistix" strips are similar in appearance to "albustix" but they are impregnated with the enzyme glucose oxidase, a peroxidase and orthotolidine. Glucose oxidase reacts with glucose in the urine to form gluconic acid and hydrogen peroxide. The hydrogen peroxide then reacts with orthotolidine to give a blue colour in the presence of peroxidase.

The same company produces "altest" tablets for the detection of protein in urine, a test based on the well-known salicylsulphonic acid reaction; and "clinitest" tablets for the detection of glucose, the principle involved being the reduction of alkaline copper sulphate by glucose.

Several workers have testified to the reliability and simplicity of these tests, especially the impregnated strips, when many specimens have to be dealt with as a routine. Hunt, Gray, and Thorogood (1956) obtained good results when comparing 170 specimens of normal and diabetic urines tested with "clinistix", Benedict's test, and an enzyme strip made by another company.

Luntz (1957) found, in comparing "clinistix" with "clinitest" tablets, that out of 942 specimens of urine 930 tests gave identical results, 916 being negative and 14 positive. Of the remainder he found that some of the urines contained reducing substances other than glucose which gave false positive results to the "clinitest", and others contained very small quantities of glucose which gave positive "clinistix" readings but no reduction in "clinitest".

Carne (1958) recommends "albustix", particularly for screening purposes. He found no false negative results but reports that he occasionally saw a false weak positive test in urine from pregnant women. Baron and Newman (1958) performed comparative tests using "albustix" and the salicylsulphonic acid test on urine with known added amounts of protein. They obtained colour changes with "albustix" when the urine contained 5 mg. of protein per 100 ml. or more. Whittet (1956) records that the "altest" tablet method was very reliable.

It was decided to carry out a trial on the routine urine tests undertaken over a period of several months. The method was to carry out the salicylsulphonic acid test for protein and the qualitative Benedict's test for glucose on all urine specimens received and to test the same specimens with "clinistix", "altest", and "albustix". The "albustix" test was not available when the trial began but was introduced as soon as possible afterwards. When positive results were obtained, quantitative tests were performed, using standard opacity tubes for the salicylsulphonic acid test and the "clinitest" tablets for glucose.

METHODS

Protein

Salicylsulphonic Acid Test.—One millilitre of urine is added to 3 ml. of 3% salicylsulphonic acid in a test tube, and the contents well mixed. Turbidity of the mixture denotes the presence of protein. This turbidity can be matched against standard opacity tubes in a range from 10 to 100 mg. per 100 ml. Should the reading be greater than 100 mg., suitable dilution may be carried out and the amount of protein present calculated accordingly.

"Altest" Tablets.—One "altest" tablet is added to 4 ml. of urine in a test tube and allowed to dissolve. The tube is gently shaken and any cloudiness appearing in the urine indicates the presence of protein.

"Albustix" Strips.—The impregnated end of the strip is immersed in the urine and removed immediately. If protein is present the moistened end turns green or blue-green usually in less than one minute.

Glucose

Benedict's Qualitative Test.—Urine, 0·5 ml., is added to 5 ml. of Benedict's qualitative reagent in a test tube. The tube is then placed in a boiling water-bath for five minutes and then cooled. If glucose is present the colour of the reagent changes to green, yellow, or orange according to the quantity of glucose present.

"Clinistix" Strips.—The impregnated end of the strip is dipped into the urine and removed immediately. If

glucose is present in the urine, the moistened end of the strip turns blue, usually within one minute.

"Clinitest" Tablets.—Five drops of urine and 10 drops of water are delivered into a test tube and one "clinitest" tablet added. As the tablet dissolves heat is generated and the fluid in the tube boils. Fifteen seconds after boiling has ceased the tube is shaken and the colour noted and compared with a colour chart which gives the approximate quantity of glucose in the urine. If no glucose is present the colour remains blue.

RESULTS

Three thousand seven hundred and six specimens of urine were tested for glucose by the Benedict's and "clinistix" methods. If either or both of these gave positive results, then the "clinitest" method was carried out. The results are recorded in Table 1.

TABLE 1
RESULTS FOR GLUCOSE

Benedict's Test	"Clinistix"	"Clinitest"	Number of Specimens
Negative	Negative	—	3,534
Positive	Positive	Positive	80
Positive	Positive	Negative	71
Positive	Negative	Negative	8
Negative	Positive	Negative	13

It is claimed by the manufacturers that the "clinistix" test is sensitive to about 0·1 g. per 100 ml. whereas "clinitest" is sensitive to 0·25 g. per 100 ml., and this contention is supported by the work of Hunt, Gray, and Thorogood (1956). This probably explains why the 84 specimens of this series which gave positive reactions with "clinistix" were negative to "clinitest". The eight specimens which gave positive reactions to Benedict's reagent and negative reactions to both "clinistix" and "clinitest" may have contained very small quantities of reducing substances other than glucose or they may have contained very small quantities of glucose. The former explanation is more likely as Benedict's reagent can be reduced by such substances as creatinine, protein, sugars other than glucose, drugs such as aspirin, and uric, glucuronic, ascorbic, and homogentisic acids.

The total number of specimens tested for protein was 3,617. The trial was divided into two series, the first in which only the salicylsulphonic acid test and "altest" were performed and the second when "albustix" strips were used in addition. The results are given in Table 2.

In the first series it will be seen that very close correlation was obtained between the salicylsulphonic acid method and "altest". In the larger second series correlation was again very close, with "altest" showing as a slightly more sensitive test than "albustix". But as the "albustix" strips are said to be sensitive to 5 mg. per 100 ml. (Baron and Newman, 1958), the slightly superior sensitivity of "altest" is of no practical value.

TABLE 2
RESULTS FOR PROTEIN

Salicylsulphonic Acid Test	"Altest"	"Albustix"	No. of Specimens
First Series			
Negative	Negative	—	1,574
Positive	Positive	—	39
Trace	Positive	—	2
Trace	Trace	—	6
Trace	Negative	—	1
Second Series			
Negative	Negative	Negative	1,958
Positive	Positive	Positive	31
Positive <10 mg. per 100 ml.	Positive	Negative	3
Trace	Positive	Negative	1
Trace	Trace	Negative	1
Trace	Negative	Negative	1

The manufacturers issue a colour chart for "albustix" and it is claimed that aproximate quantitation may be achieved by comparing the colour change on the strip with the chart which gives colours for 30 mg., 100 mg., 300 mg., and over 1,000 mg. of protein per 100 ml. of urine. This rough estimation of quantity may be useful in the field but it is considered that where laboratory facilities are available, the quantitative salicylsulphonic acid test should be performed on all urine specimens showing a positive reaction to "albustix".

CONCLUSIONS

The results of this trial show that the detection of significant amounts of glucose and protein in specimens of urine received for routine examination may be rapidly and accurately carried out by the use of the impregnated strips "clinistix" and "albustix" respectively. If preferred "altest" tablets are eminently suitable for detecting protein.

I am grateful to Dr. P. R. Boyd for his encouragement and permission to undertake this trial, and Messrs. R. L. Harding, A. Hickson, and F. N. Hine for their technical assistance.

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OBITUARIES

A. Treve Holman, O.B.E., J.P.

Mr. A. Treve Holman, O.B.E., J.P., M.I.Mech.E., Chairman of Holman Brothers Limited, Camborne, Cornwall, died suddenly on June 6, 1959, while on a business visit to Lisbon.

Treve Holman was an industrialist of high attainments and a practical engineering expert who, from his apprenticeship days, prided himself on personal knowledge of the firm's work from shop-floor level upward.

His company has branches in almost every country in the world and there can be few metal-mining camps of any size where his name was not familiar.

Mr. Holman's major interest was in the firm's research and experimental department, whose development was largely his achievement. He was a man of keen inventive mind, boundless energy, and with a warm humanity which made his firm a family concern in every sense.

A real Cornishman, he knew at first hand the tragedy that silicosis has been in his home county, and he believed that the remedy was an engineer's problem. His design and development of the "dryductor" rock drill (which extracts dust dry, at the tool-point, under high vacuum with low-volume airflow) was his great contribution in this field; the principle has been applied in foundries and factories as well as in mines.

His paper on mining, silicosis, and rock removal (*Brit. J. industr. Med.*, 1947, **4**, 1) is a standard work of reference on the subject.

Holman Brothers' works and experimental quarries were constantly visited by industrial doctors from all over the world, and despite a host of professional and public activities Treve Holman and his staff were always generous of their time and their experience. This was a further valuable contribution, for which many of us who admired his quality will remember him gratefully.

Lasar Dunner, M.D. (Berlin)

Dr. Lasar Dunner died at Hull on June 6, 1959. He was born on June 14, 1885, in Cologne, of Jewish parentage, and took the M.D. (Berlin) in 1912. Full details of his career in Germany are not available, but it is known that he became Medical Director to the Buch-West Hospital and Physician-in-charge of the department for lung diseases at the Jewish Hospital in Berlin. He was obliged to leave Germany in the middle 1930s with the advent of the Hitler régime and he obtained an appointment at the Tuberculosis Dispensary in Hull under Dr. Diamond. With his extensive knowledge of tuberculosis and other chest diseases, he became a valued member of the dispensary staff. During the late 1930s, Diamond began to collect case histories of boiler scalers who showed evidence of pneumoconiosis, and in consequence Dunner became interested in industrial chest diseases. After Diamond's death during a bombing raid, Dunner took over the investigation, and published a series of papers on occupational disease of the lungs in boiler scalers. Subsequently with his colleagues, Hardy, Hermon, and Bagnall, he took advantage of the wealth of clinical material in Hull and published papers on lung disease in workers exposed to the dusts of graphite and ultramarine, and these were followed by observations on the effects of sulphur dioxide and fumes of coke fires on the lungs as well as by studies of dockers who handle grain and seeds. He also published a paper on iron fettlers' pneumoconiosis. Apart from these contributions to industrial medicine, he published well over 100 papers on clinical and experimental work in chest diseases, and he was the author of five textbooks in German on such subjects as the differential diagnosis of lung diseases, percussion and auscultation (with R. Neumann), syphilis of the lung, and pulmonary tuberculosis.

Dunner was a man of great energy, with a lively mind and great personal charm. He came to this country at an age when he could not adapt himself fully to the English atmosphere and personalities, so in some respects he was a lonely figure. He had great courage and persistence, and it was entirely due to his efforts that an industrial chest diseases clinic was set up in Hull with himself as honorary physician in charge. In this and other capacities he has served the country of his adoption well. Dr. Dunner was unmarried.

BOOK REVIEWS

Taschenbuch der Arbeitsmedizin. By H. Buckup. (Pp. viii + 272; 19 figures. DM. 27.00.) Stuttgart: Georg Thieme Verlag. 1957.

A pocket book on industrial medicine designed for *all* interested in the subject was the target of the author of this little volume, "little" in size but astonishingly packed with information arranged in alphabetical order. Since the volume is meant to be used for quick reference the author has had to be very selective in choosing the items. This was clearly made possible by his wide experience in the Ruhr. Such items as lead, hydrocyanic acid, arsenic, mercury, and others in our own list of notifiable industrial poisonings and diseases are given understanding and relatively detailed emphasis. On the other hand occupational skin disease as a distinct section is perhaps passed over too quickly although skin effects are referred to in the consideration of separate substances. Among the many inorganic and organic compounds which have become increasingly important, one is glad to note significant space given to cadmium, isocyanates, trichloroethylene (author gives 1,024 mg./m.^{3} as M.A.C., *i.e.*, about 180 p.p.m. and mentions that the Russians quote 50 mg./m.^{3} as M.A.C., *i.e.*, about 9 p.p.m.), synthetic resins, and polymers, epoxy (ethoxyline) resins, ethylene glycol dinitrate, and many others. In a useful little table giving the symptomatology of chlorinated hydrocarbon intoxication we note that the author includes hexachlorocyclohexane among the aromatics (!) and attributes central and peripheral nervous effects to methylene chloride (dichloromethane). This latter point requires correction, we suggest, unless chapter and verse can be given for it. The organic phosphorus insecticides receive significant space but it is perhaps impossible to summarize present knowledge on these compounds in a few hundred words.

Tabulating the New York Department of Health list of the confirmed and probable occupational carcinogens, the author includes "isopropyl oil" (a somewhat volatile hydrocarbon product of the interaction of sulphuric acid on propylene) as a certain lung and nasal sinus carcinogen, although it is dubious whether H. F. Smith's quest for a carcinogen (1952) a few years ago in the manufacture of isopropanol really led to more than a suspicion, although he had certainly found a high incidence of cancer of these parts among the workers.

It will perhaps be a surprise to some readers that the use of crude $NaNO_2$ is stated to be probably associated with cancer of the skin. On the other hand the inclusion of o-toluidine and chloro-toluidine as bladder carcinogens and of chlorinated hydrocarbons as probable hepatic carcinogens is, as far as we know, far from being confirmed or generally accepted. Even crude anthracene, as a skin carcinogen, must rather be regarded as a complex mixture jointly, in some tar distilleries, containing carcinogenic agents of composition distinct from anthracene. On the other hand, the author gives benzidine as only a "probable" bladder carcinogen, whereas nothing can be more certain.

In the field of more general interest in occupational medicine, we cannot refrain from quoting the author's words on pay: "Pay should correspond to production and should assure the needs of life for the worker and his family; equal pay should be given to women, men, and young persons for equal work. . . . The nature and magnitude of pay can have a significant industrial medical influence." He makes a special point that whereas a supplement in pay is not recommended because there are health hazards, it is recommended because of the working difficulties entailed by the use of protective methods. This seems to us a sensible point of view inasmuch as many workers in this country seem to imagine that "dirt and danger money" is a kind of insurance against hazard.

The curve relating the hour-to-hour variation of working capacity to variations in blood adrenaline (and precursor) shows the well-known maxima and minima during the day and the curves showing the great physiological diminution in pulse pressure in the early hours of the morning will be of much interest to works medical officers who have to do with night shifts.

The largest section in this really interesting book (or compilation) is that on dust diseases of the lung. Having given the limits of "safety" of dust concentration for dusts of varying silica content recognized in the U.S.A., U.S.S.R., Britain, and Belgium, he proceeds to give the German formula, which attempts the calculation of a figure for dust value (*Staubwertzahl*) making allowance for the silica content of the constituent minerals of the dust and for the fine dust concentration (m/v), the dust value being equal to (*mineral value* $\times$ *fine dust concentration*)/10. A dust value below 50 is regarded as not serious, but values over 100 imply an urgent demand for protective measures. We are unable to say how valuable this arithmetical approach is. The German proposal for a simple graphical, radiological, international classification of silicosis is also given and is worth careful comparison with the more detailed classifications proposed by other countries. For those who possess the German language, this little book is a worth-while purchase.

M. W. GOLDBLATT

Health in Industry. By Donald Hunter. (Pp. 288; 18 plates. 4*s*.) London: Penguin Books. 1959.

A volume of the Pelican Medical Series should be exciting enough to have popular appeal but carry authority so that it can be read with confidence not only

by doctors, but by all those interested in the subject. The author has succeeded in his difficult task and his book will stimulate doctors reading it to take more interest in their patients' working environment, and laymen to appreciate the part they can play in making industry safer. It stresses the value of the team, including physicians, chemists, engineers, employers, and employees, in tackling industrial accidents and hazards.

The history of industrial medicine is frankly and graphically told, and the summary of legislation affecting working conditions is factual and clear.

The importance of accident prevention is demonstrated by descriptions of the hazards met with in a number of heavy industries.

The second half of the book is principally concerned with prescribed diseases, but also includes some excellent sections on dangerous materials not yet in this category. Accounts of various disasters, when inadequate precautions were taken, in handling organic compounds, such as insecticides, should be a warning to all who are concerned with the manufacture, marketing, and application of new potentially dangerous chemicals.

To assist the layman there is a glossary of technical terms, and the author, having stimulated his reader's interest in this important subject, provides a list of books and papers for further study.

It is to be hoped that subsequent editions will include a chapter on the place of epidemiological and statistical methods in investigating accidents, industrial hazards, and the causes of sickness absence.

W. E. CHIESMAN

Industrial Health Technology. By Bryan Harvey and Robert Murray. (Pp. xiii + 337; 78 figures. 45*s*.) London: Butterworth. 1958.

This should prove a useful book for all those concerned with the health of the industrial worker, including executives and trade unionists. For, as the authors wisely state in their preface, "The health of the industrial worker does not lie in the hands of those whose training makes them experts in this subject but of those who control industry . . .". For the new industrial medical officer, too, it provides an excellent summary of occupational diseases and control methods in a great number of industries. For the expert, its value—although still considerable—is limited by a tantalizing lack of references: there are only 36 in the entire book.

The book is divided into three parts. The first part describes the physical, biological, and chemical causes of industrial diseases. There are some excellent simple accounts of such things as radiant energy and the chemistry of the hydrocarbons which can be understood without previous technical knowledge.

In the second part the principles of the prevention of industrial disease—substitution, segregation, enclosure, exhaust ventilation, wet methods, protective clothing—are described and an account of air sampling and analysis is given. The extensive practical experience of the authors is apparent and many examples are given to illustrate the underlying principles. The chapter on exhaust ventilation, the longest and one of the best in the book, combines a simple theoretical explanation of air flow, with a practical account of the design of ventilation systems. The tables of air engineering data, which are also included, are unlikely to be used by many readers; but they serve to illustrate some of the technical problems.

The third part of the book concerns the comfort of the worker which, though it cannot be divorced from his health, requires environmental conditions better than the minimum necessary to prevent illness. It contains chapters on ventilation and heating, lighting and colour, and noise. A short, carefully chosen bibliography is given. Also, there is a 10-page glossary of chemical substances commonly used in industry. For each substance is given the chemical formula, physical state, main uses, its most likely mode of entry into the body, and its chief effects.

The inevitable difficulty of presenting technical information simply and concisely to readers with differing background knowledge and differing needs for new information is apparent in this book. For example, the authors could be criticised for omitting some detail which should properly be included in a comprehensive treatise: on the other hand, it is possible to argue that there is already too much detail and that more would deter those who should be encouraged to read the book. On the whole, the authors are to be congratulated on their selection of material and cannot be accused of oversimplification.

This, the first book of its kind from this side of the Atlantic, is a valuable contribution to bridging the gulfs which exist between medicine, industrial hygiene, and industrial management. The authors state that "the reader of this book will not necessarily discover how to swim, but it is hoped that he will learn to judge the depth of the water". Industrial medical officers should have this book and lend it to their non-medical friends.

C. H. WOOD

Manuale di Medicina del Lavoro, 2nd ed. By F. Molfino. (Pp. 890. Lire 10,000.) Turin: Ed. Minerva Medica.

The author has developed the classification of the first edition and many additional conditions are discussed.

After a short review of recent developments he describes the various human physiological types, noting the average proportions and the usual relationships between height, chest measurement, and weight. It is pointed out that many persons vary so much from the normal as to be handicapped when using conventional equipment. Accident proneness also receives attention.

Methods for studying fatigue are described together with measures to lessen its severity. The effects of physical agents are described and in this section recent work on the effects of raised or lowered atmospheric pressure is noted.

Among the infections commonly contracted from certain special kinds of work Molfino includes epizootic foot and mouth disease, Q fever, ankylostomiasis, and many others. Dust diseases receive attention, and there is a good chapter on the symptoms caused by vibrating tools, for which dihydroergocornine and other ergot

derivates have been given with good results. Under a recent Italian law all workers using vibrating tools are required to undergo an annual medical examination.

In some ways Italian law seems ahead of that of other countries, particularly in the recognition and introduction of regulations to limit new hazards. Thus beryllium was early recognized as a highly toxic material and those working with it appear to be adequately safeguarded. This is also the case with the industrial use of fluorides.

This book is attractively produced and contains many useful illustrations and figures.

G. C. PETHER

Die Staublungenerkrankungen, Vol. III. Reports of the third international conference on dust diseases of the lung held in 1957 at Munster University. (Pp. xvi + 607; 319 figures. DM. 62.00.) Darmstadt: Dr. Dietrich Steinkopff Verlag.

This volume contains reports of the third international conference on dust diseases of the lung held in 1957 in the department of hygiene and industrial medicine of Munster University.

The first part is devoted to fundamental research with particular reference to the effects of silicates.

The next part deals with trace elements and the relationship between them and the formation of silicotic lesions. A group of contributors investigated the effects of various constituents of the dust to which workers in the Ruhr coalfields are exposed.

The relationship between emphysema, bronchitis, and silicosis received attention and the importance of cor pulmonale when these are present was noted. Some contributors consider that there is a constitutional factor operating in some cases of emphysema and it has been shown that examination at necropsy will give not only an accurate measure of the elasticity of the lung but also of the capacity of its vessels. Elasticity is highest when growth ceases and is little altered until the fiftieth year after which it falls.

The vessels in a silicotic lung degenerate so that in time various complications such as thrombosis or even obliteration occur. Pulmonary sclerosis is common, and though some ascribed it to the effects of an existing high pulmonary pressure, others thought it might sometimes be linked with locally occurring sclerosis and thrombotic processes.

To diminish the incidence of silicosis it is necessary not only to keep workers under constant observation but also to be able to change their work before much damage has been done. In Switzerland the intervals between systematic examination of employees vary from trade to trade so that miners, depending on age, are seen every year, or two years, while workers in other industries with a dust hazard are seen less often. Should evidence of undue sensitivity to dust be apparent soon after work begins, it is considered reasonable to advise that a different occupation be chosen.

In the last section of the book a number of interesting individual contributions is found. Some deal with the association of pulmonary tuberculosis with dust diseases and the difficulty of diagnosis of this condition on radiographic evidence alone is stressed.

A new material invented by Krupp and known as *hartmetall* has come into industrial use. It has about 95% of the hardness of diamonds and is made from tungsten carbide, cobalt, titanium carbide, and tantalum carbide. These are mixed together and then fused at a temperature of 1400 to 1600° C.

In 1940 the first cases of lung damage attributed to *hartmetall* were notified.

It appears that the individual constituents may each have harmful effects. One worker took up employment at the age of 21 but by his 27th year had such severe dyspnoea that he had to give up. The clinical picture is similar to that seen in the aluminium industry in the Rhein-Main area. Spectrographically the lung had a high content of tungsten and titanium but less cobalt. There is evidence that the liver as well as the lung may suffer in this industry.

Lung injury from vegetable dusts received attention from an English contributor and in the discussion the value of microscopic examination of lymph nodes from the scalenus area was described. This procedure is commonly used in Sweden.

In the field of prophylaxis the value of aerosols is discussed and in some animal experiments certain aluminium preparations gave good results.

This book contains much interesting material, though much of it is necessarily speculative or controversial.

G. C. PETHER

The Pneumoconiosis Problem: With Emphasis on the Role of the Radiologist. By Eugene P. Pendergrass. (Pp. x + 146; 53 figures. 51*s*.) Oxford: Blackwell Scientific Publications; Springfield, Illinois: Charles C. Thomas. 1958.

This book, by an eminent American radiologist who has made many valuable contributions during the past 30 years to the literature of the pneumoconioses, is concerned with silicosis, asbestosis, and coal workers' pneumoconiosis. No attempt has been made at an exhaustive treatise which would have been impossible in a work of this length but many facets of the history, pathogenesis, clinical and physiological features of pneumoconiosis are presented, compensation issues are touched on, and the radiological changes are considered in greater detail. The author's wide experience and judicious selection of the world literature has resulted in a very well balanced account of these three pneumoconioses. The reproductions of the chest radiographs, so important to the success of a book of this kind, are printed as negatives and are of a sufficiently high standard to illustrate the points being made, though No. 23 has unfortunately been reproduced upside down.

The author's recommended radiographic routine for workers in an industry with a dust hazard (six pre-employment chest films repeated five yearly with a single film during the intervening years) seems excessive but apart from this one reservation "The Pneumoconiosis Problem" can be strongly recommended.

I. T. T. HIGGINS

The Preservation of Eyesight. By Sir Arthur Salusbury MacNalty. (Pp. vii + 109; 9 figures. 12*s.* 6*d.*) Bristol: John Wright. 1958.

This book is claimed to be the first of its kind since 1616 when Walter Baily, Regius Professor of Physic at Oxford, wrote his treatise on the same subject. Few will quarrel with this claim and it is interesting to think of the type of people to whom this modern work will appeal. Many practitioners fight shy of ophthalmology; this book should help to stimulate interest in the subject, however late in life it may be read. Industrial medical officers, nurses, and social workers will acquire useful knowledge from reading it; advice is given on everyday matters dealing with the care and precautions necessary to maintain good eyesight.

The early chapters deal adequately and simply with anatomy, physiology, and elementary optics. (A useful addition would have been a brief description of the protective mechanisms of the eye, both anatomical and physiological, as this would have given the reader more confidence in the ability of Nature to safeguard the sight against injury.)

Ocular nutrition and its relation to variations in diet are considered. A simplified and well constructed explanation of common refractive errors is given, but reference to "colour *blindness*" instead of "*colour vision defect*" could possibly be open to criticism.

Common eye diseases are described and the difficulty of imparting too much knowledge on treatment to a lay person is neatly overcome by the simple expression "the doctor may prescribe, . . ." After giving the signs and symptoms of acute glaucoma, it is stated that if the patient consults an ophthalmic surgeon he will be recommended to have an iridectomy. Some ophthalmic surgeons will not agree that this is invariably necessary.

The "Eye in Old Age" presents a homely description of presbyopia, and of the senile cataract there is a comforting account of onset, progress, and treatment that should be easily readable by a lay person, without misunderstanding or creating anxiety in the mind of the reader who may be suffering from this condition. Stress is rightly laid on the steps that can be taken to reduce the handicap of a developing cataract to a minimum in cases where the period of waiting for operation is often tedious.

Of particular interest in the field of industrial medicine is the part dealing with the statutory provisions for blind persons and explanation of the National Assistance Act 1948, Sections 21 and 29. This is followed by a description of the function of authorities and voluntary organizations under the Blind Persons Act of 1920 and 1938 and they act as a useful guide to industrial medical officers when dealing with such cases from the welfare angle. One cannot help being impressed by the arguments used to support the employment of blind persons in such occupations as typists, telephonists, repetitive assembly workers, piano tuners, masseurs, and the musical arts. Ninety-six thousand, and nineteen is a startling figure for blind persons registered at the end of 1956 in England and Wales and equally telling is that of the 200,000 eye injuries occurring in industry annually (most of which are preventable).

The difficulty is mentioned, alas so prevalent, of persuading employees to wear goggles when engaged on "eye risk" occupations. Hardened or toughened glass is recommended, also laminated glass, but it is possible that research will show that laminated plastic lenses are much safer, particularly for foundryworkers.

This simply worded and common-sense book should appeal to a large variety of readers.

C. T. NEWNHAM

Journal of Occupational Medicine: Vol. 1, No. 1, January, 1959. Published monthly by the Industrial Medical Association, 28 East Jackson Boulevard, Chicago, 4. ($10.00 per annum, single copies $1.00.)

The publication of this new journal means that the Industrial Medical Association now owns and publishes its own journal. The Industrial Medical Association has gone through a long period of steady, solid growth, and is prepared for the responsibility of ownership and management of a major publication. Recognition of industrial medicine has also been achieved in another field: specialty status has been granted to occupational medicine under the American Board of Preventive Medicine, and several major universities devote substantial resources to graduate training programmes in this specialty. This is progress indeed. But it must be remembered that the Association of Industrial Medical Officers established its own *Transactions* some years ago. The *Journal of Occupational Medicine* has a strong editorial board; it is attractively produced. It will be hard work to maintain this standard for a journal produced monthly. The Industrial Medical Association has the opportunity to produce a journal which will be a valuable addition to the literature and we wish it every success.

L. G. NORMAN

BOOKS RECEIVED

(Review in a latter issue is not precluded by notice here of books recently received)

Underwater Escape from Aircraft. By J. W. Norman [Reprint from *Admiralty Bulletin* No. 104]. Royal Naval Scientific Service, Admiralty Hydro-Ballistic Research Establishment. January, 1959.

A Comparison of the United Kingdom Tariff and the Proposed Tariff of the European Economic Community. Prepared by the Economist Intelligence Unit Ltd. (Pp. 16 foolscap + 14 tables. 10*s.*) London: Federal Trust for Education and Research. 1959.

Public Good or Official Prejudice? Second edition. (Pp. 16; pamphlet.) Committee for Homeopathy in Universities and Teaching Hospitals (A. W. Hopkins, St. Albans). 1959.

The Ciba Foundation for the Promotion of International Co-operation in Medical and Chemical Research. Report for 1958. (Pp. 52.) London. 1959.

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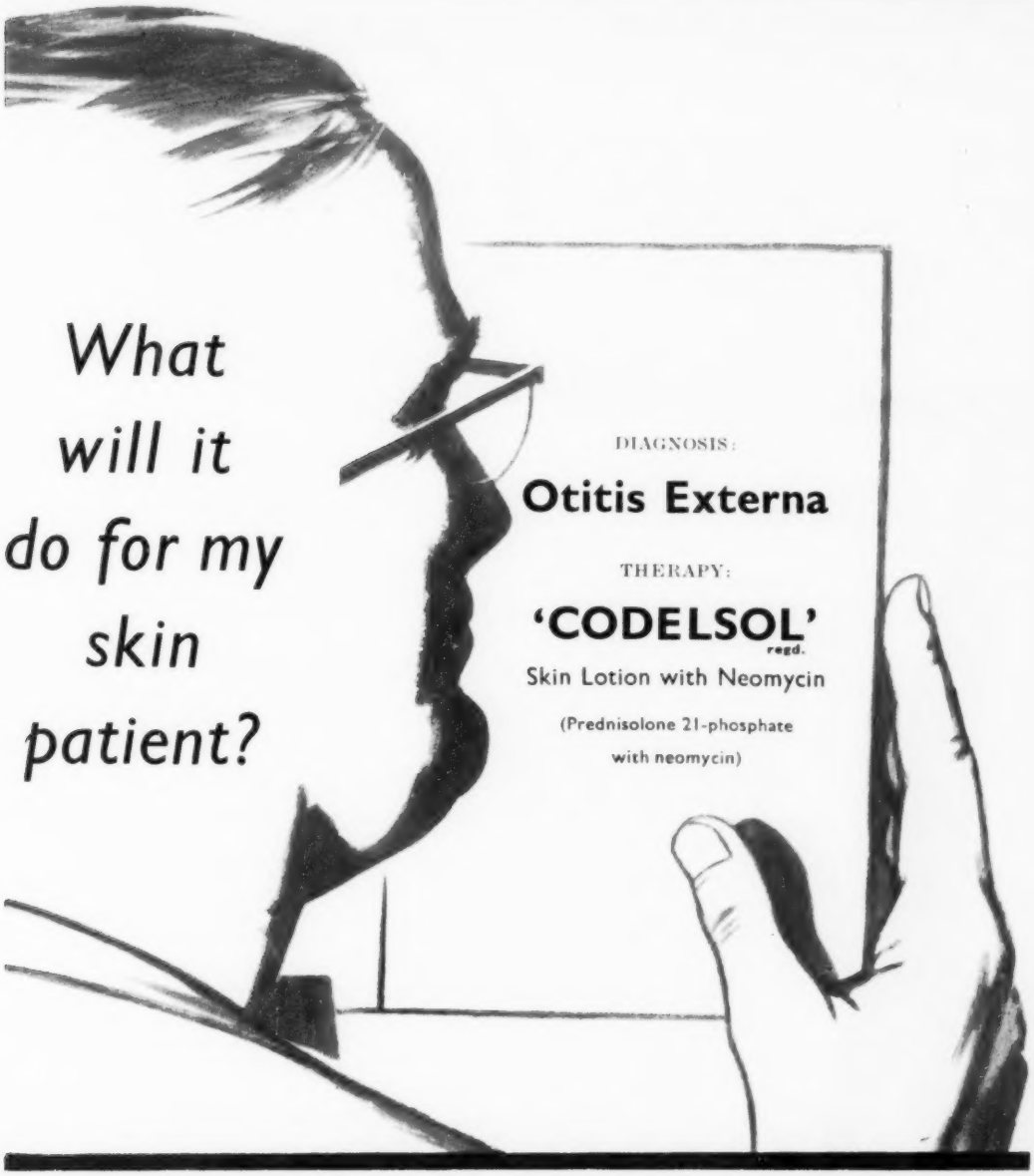

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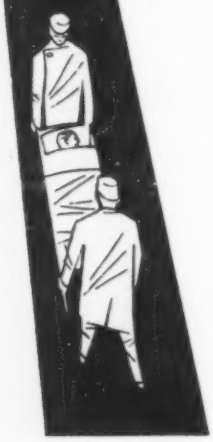

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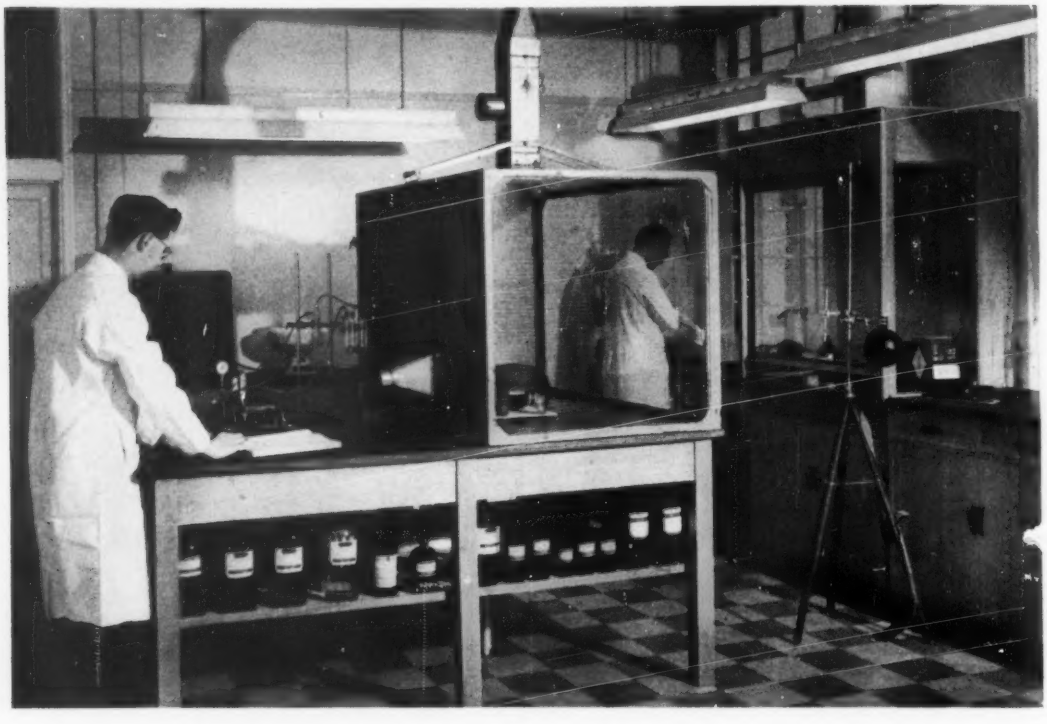

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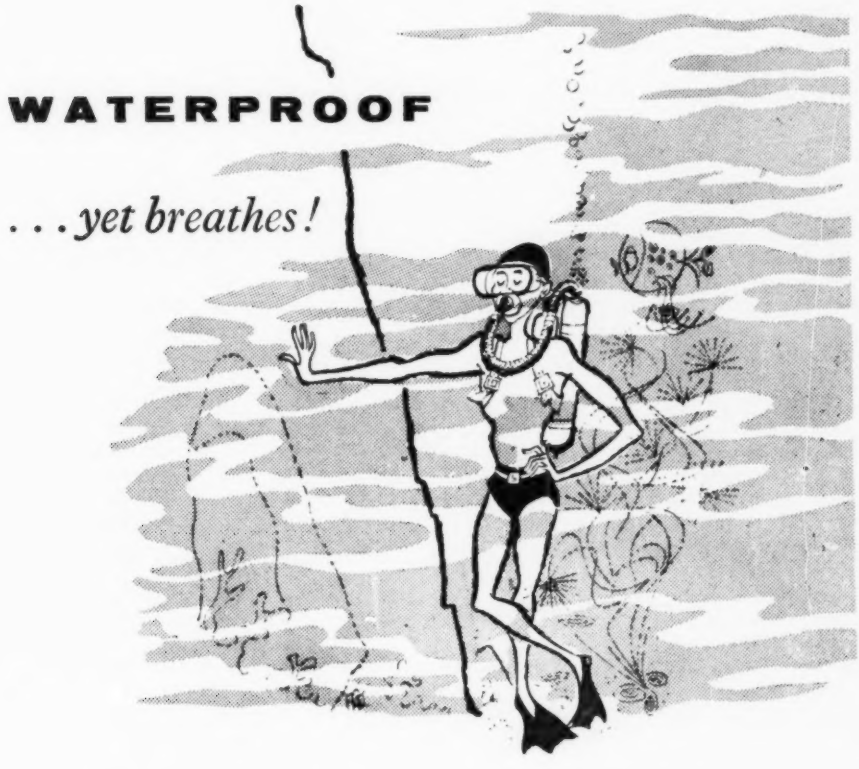

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